NOTICE

All drawings located at the end of the document.

0000 13838

TECHNICAL MEMORANDUM

REVISED FIELD SAMPLING PLAN AND DATA QUALITY OBJECTIVES

THE WEST SPRAY FIELD (IHSS 168) OPERABLE UNIT NO. 11

WORKING DRAFT

ROCKY FLATS PLANT

U. S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

ENVIRONMENTAL RESTORATION MANAGEMENT

ADMIN RECORD

DOCUMENT CLASSIFICATION
REVIEW WAIVER PER
CLASSIFICATION OFFICE

A-OU11-000074

Table of Contents

Executive Summary ES-1

1.0 Introduction 1-1
1.1 Background 1-1
1.2 Purpose and Scope 1-3

2.0 Assessment of Existing Data 2-1
2.1 Gamma Surveys 2-2
2.2 Surface Soil Sampling and Test Pits 2-5
2.3 Groundwater Monitoring Activities 2-9

3.0 DQO Process 3-1
3.1 Stage 1 -Identify Decision Types 3-2
3.1.1 Identify and Involve Data Users 3-3
3.1.2 Evaluation of Available Data 3-3
3.1.3 Conceptual Site Model 3-4
3.1.4 Objectives of Revised FSP 3-8
3.2 Stage 2 - Data Uses/Needs 3-9
3.2.1 Data Uses 3-9
3.2.2 Data Types 3-9
3.2.3 Data Quality 3-12
3.2.4 Data Quantity 3-13
3.2.5 PARCC Parameters 3-13
3.3 Stage 3 - Data Collection Program 3-14

4.0 Sampling and Analysis Plan 4-1
4.1 Objectives and Approach 4-1
4.2 Contaminants of Concern 4-1
4.2.1 Method of Evaluation 4-2
4.2.2 Evaluation of Results by Media 4-6
4.2.3 Summary and Conclusions 4-10
4.3 Proposed Activities and Locations 4-13
4.3.1 Ecological Field Sampling Plan 4-13
4.3.2 Soil Sampling 4-20
4.3.3 Monitoring Wells 4-21
4.3.3.1 Well Locations and Justification 4-21
4.3.3.2 Monitoring Well Installation Program 4-24

5.0 Quality Assurance/Quality Control 5-1
5.1 Internal QC Control Samples 5-1
5.2 Accuracy 5-2
5.3 Precision 5-3
5.4 Sensitivity 5-3
5.5 Representativeness 5-3
5.6 Data Comparability 5-4
5.7 Completeness 5-4
5.8 Sample Management 5-4
5.9 Data Reporting 5-4

6.0 Schedule 6-1

7.0 References 7-1

Appendices

APPENDIX A ISOTOPE RATIO METHOD FOR DETERMINING URANIUM CONTAMINANTS AT OU 11
APPENDIX B MATHEMATICAL ANALYTICAL MODEL
APPENDIX C CONTAMINANTS OF CONCERN TABLES
APPENDIX D PRG DETERMINATION METHOD
APPENDIX E ECOLOGICAL SAMPLING TABLES

List of Tables

TABLE 2-1 RESULTS OF THE HPGE SURVEY AT THE WEST SPRAY FIELD 2-3
TABLE 3-1 DECISION TYPES, MAKERS AND DATA USERS FOR THE OU 11 RFI/RI PROCESS 3-2
TABLE 3-2 OBJECTIVES AND ACTIVITIES OF THE REVISED FIELD SAMPLING PLAN 3-12
TABLE 4-1 ANALYTICAL SUITES AND MEDIA SAMPLED FOR OU 11 4-2
TABLE 5-1 FIELD QA/QC SAMPLE COLLECTION FREQUENCY 5-2
TABLE 5-2 SAMPLE CONTAINERS, SAMPLE PRESERVATION, AND SAMPLE HOLDING TIMES FOR OU 11 CONTAMININTS OF CONCERN 5-6
TABLE A-1 URANIUM ISOTOPE RATIOS A-5
TABLE B-1 CALCULATED EAST-WEST PROFILE OF MOUND ACROSS AREA 1 . . . . . B-6
TABLE C-1 SELECTION OF POTENTIAL CONSTITUENTS OF CONCERN FOR OU 11 ALLUVIAL GROUNDWATER C-1
TABLE C-2 SELECTION OF POTENTIAL CONSTITUENTS OF CONCERN FOR OU 11 BEDROCK GROUNDWATER C-5
TABLE C-3 SELECTION OF POTENTIAL CONSTITUENTS OF CONCERN FOR OU 11 SURFACE WATER C-6
TABLE C-4 SELECTION OF POTENTIAL CONSTITUENTS OF CONCERN FOR OU 11 SURFACE SOILS C-7
TABLE C-5 SELECTION OF POTENTIAL CONSTITUENTS OF CONCERN FOR OU 11 SUBSURFACE SOILS C-9
TABLE E-1 ECOLOGICAL SAMPLING MATRIX E-1
TABLE E-2 ECOLOGICAL SAMPLING DESIGN E-5

List of Figures

FIGURE 1-1 AREAS OF SPRAY APPLICATION 1-2
FIGURE 2-1 TERRESTRIAL GAMMA RAY EXPOSURE RATE AT ONE METER ABOVE TERRAIN EXTRACTED FROM THE GROSS COUNT RATE DATA 2-4
FIGURE 2-2 HISTORICAL SAMPLING ACTIVITIES AT THE WEST SPRAY FIELD 2-6
FIGURE 3-1 SCHEMATIC DIAGRAM OF OU 11; THE WEST SPRAY FIELD 3-5
FIGURE 3-2 PROCESS FLOW DIAGRAM 3-9
FIGURE 4-1 EVALUATION OF CONTAMINANTS OF CONCERN 4-3
FIGURE 4-2 LOCATIONS OF PROPOSED MONITORING WELLS 4-23
FIGURE B-1 EAST-WEST PROFILE OF MOUND ACROSS AREA 1 . . . . . A-5

This Technical Memorandum (TM) presents the Revised Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) Field Sampling Plan (FSP) and Data Quality Objectives (DQOs) for Operable Unit 11 (OU 11), West Spray Field. This FSP refines and focuses the scope of work for investigation that was presented originally in the OU 11 Phase I RFI/RI Work Plan (EG&G 1992a). This focusing of scope is appropriate based upon a compilation and rigorous statistical review of historical data, recent screening surveys, and current monitoring activities, most of which were not incorporated into the original OU 11 Work Plan FSP. These data indicate that substantial contamination from spray application of solar pond water onto the West Spray Field does not exist.

OU 11 is classified per the Interagency Agreement (IAG) as a RCRA lead OU. The implications of this designation are that the process by which this OU is investigated has been broken into two separate phases of investigation. The initial phase investigates the nature and extent of contamination within the "source and soils". This has been interpreted as the surface and shallow subsurface of the field. The next phase investigates the "nature and extent" of contamination that may have or has the potential to migrate outside the boundaries of the OU. These phases are defined in Attachment 2, Section I.B.11.b of the IAG.

RCRA Subpart G Part 265.111(b) requires a closure performance standard that "controls, minimizes, or eliminates (contamination) to the extent necessary to protect human health and the environment". This corresponds to equivalent guidance from the Colorado Hazardous Waste Act (CHWA). Compliance to this requirement is demonstrated by controls that can be established to mitigate any identified risk. The risk assessment process is divided into two separate assessments since the data necessary to assess risk from all potential pathways (i.e. groundwater, air, etc.) is provided by two separate field investigations. The Phase I risk assessment evaluates risk from the "upward pathways" only (i.e. exposure from air transport or direct contact). Phase II evaluates exposure from contaminated groundwater or surface water.

The Revised FSP is directed towards acquiring data to determine if potential sources exist within OU 11 that might present a risk to human health or the environment. To accomplish this goal, activities from the Phase I investigation have been combined with standard Phase II investigation activities. These combined activities have been streamlined and focused to provide an investigation that will allow the early assessment of risk and will eventually provide a complete RFI/RI Report combining both phases for public presentation several years in advance of the original Interagency Agreement (IAG) schedule.

1.0 INTRODUCTION

1.1 BACKGROUND

As part of the Rocky Flats Environmental Restoration program, a multiple phased Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) was proposed for Operable Unit 11 (OU 11), the West Spray Field (WSF). The WSF is located on the west side of the Rocky Flats Plant (RFP) and covers an area of approximately 105.1 acres.

From April 1982 until October 1985, the WSF area was used for periodic spray application of excess liquids pumped from the Solar Evaporation Ponds 207-B North and 207-B Center. Pond 207-B Center was a repository for treated sanitary effluent, whereas Pond 207-B North was a repository for water from the interceptor trench system (ITS). The ITS was installed to collect groundwater and seepage from the hillside north of the Solar Evaporation Ponds and water from the Building 771 and 774 footing drains.

The total combined area of direct application is approximately 14.1 acres, and is divided into three areas. Area 1 is approximately 35.6 acres in size and accommodated three fixed spray lines (two were previously portable lines) with a width of 80 feet and an average length of 1,524 feet. The resulting spray area for all three lines was 8.4 acres. Area 2 covers approximately 2.5 acres and accommodated a single fixed irrigation line. A spray impulse cannon with a maximum spray radius of 100 feet was used on an east-west trend in Area 3 (3.2 acres). Figure 1-1 illustrates the three areas of spray application.

Based on the total volumes applied between April 1982 and October 1985 - and the estimated areas of application of 8.4, 2.5, and 3.2 acres for Areas 1, 2, and 3, - a total average was estimated. The estimated total application of Pond 207-B North water is about 40 inches of liquids applied in Area 1. The estimated total application of Pond 207-B Center liquids is roughly 150 inches, applied in Areas 1, 2, and 3. Because liquid from both ponds were applied to Area 1, the maximum total application could have been as much as 190 inches per unit area

for all four years of operation.

The water collected from the ITS and pumped to Pond 207-B North has been characterized (U. S. DOE, 1992) as containing elevated nitrate, chloride, and sulfate. The most prevalent metals were sodium, potassium, calcium, and magnesium. Radionuclide concentrations were highest for uranium-234 and uranium-238. The only organic compound detected was methylene chloride, although this compound was also noted in blanks and its presence is attributed to laboratory contamination.

Liquids from Pond 207-B Center were applied to all three application areas. This water consisted of treated sanitary effluent from the RFP sanitary waste-water treatment plant, which was characterized by elevated nitrate concentrations.

1.2 PURPOSE AND SCOPE

Purpose

The purpose of this Technical Memorandum is to integrate Phases I and II of the OU 11 RFI/RI field investigations and applicable documents in order to perform a risk assessment and justify a final action for the West Spray Field. This will be accomplished by streamlining both phases thereby eliminating the need for interim studies and investigations. Existing data will be used to their fullest extent to support this effort.

Scope

The scope of this Technical Memorandum is limited to the following tasks:

1. The implementation of a field investigation to support a comprehensive assessment of potential sources and pathways at OU 11. Field efforts will include:

- HPGe field screening for potential radiological contamination;

- Vadose zone investigations to assess the nature and extent of potential contamination

and to assess the viability of this as a contaminant transport pathway and;

- Ecological impacts assessment to determine if there is evidence of impacts from past practices at OU 11.

2. The evaluation of historical and current data will provide justification for final action recommendations. Specific data to be examined include 1988 test pit analytical data, historical and current monitoring well activities, and solar ponds process knowledge.

2.0
ASSESSMENT OF EXISTING DATA

Several investigations previously performed in the OU 11 area provide useful information for this field sampling program. Data from surface radiation surveys, historical soils investigations, and ongoing groundwater monitoring activities were assessed to locate data gaps needing further investigation. This section will provide an overview of previous, current and ongoing studies at OU 11. Section 4 of this TM goes into further detail of actual contaminant levels.

Much of the historical investigatory work for OU 11 was a result of the need for a Part B Permit Application for several units including the West Spray Field, which was identified as a land application unit. As part of the Permit Application, a site characterization report was prepared which addressed the technical descriptions of the geology and hydrogeology of the site. Although the West Spray Field was not operating at the time, a closure plan was developed to provide a regulatory means to cease operation of land application. Closure performance standards and soil sampling programs were developed as part of the closure plan. Additional information regarding the characterization efforts are provided in the closure plan developed in 1986 and the revised closure plan of 1988 (Rockwell, International, 1988a).

The soil and groundwater data described in Sections 2.2 and 2.3 respectively, were evaluated for the impact of West Spray Field activities on those media. This provides data obtained over a period of six years that have been used to study temporal trends. Certain analytes in the soil and groundwater are of concern because concentrations are elevated relative to either background surface soil values from the Rock Creek area or to concentrations in RFP background groundwater as presented in the 1992 Background Geochemical Characterization Report (EG&G, 1992b).

2.1 GAMMA SURVEYS

Two gamma surveys have been conducted at the West Spray Field. In July of 1989, an aerial gamma survey of the Rocky Flats Plant and surrounding areas was performed by EG&G Energy Measurements. The aerial survey, which measured natural and man-made gamma radiation, provided an estimate of the distribution of isotope concentrations around the plant. Results were reported on isoradiation contour maps, including measurements of americium-241 and cesium-137 (EG&G/EM, 1989). A ground-based High Purity Germanium (HPGe) gamma survey was performed at Operable Unit 11 in September and October of 1993 in order to determine if further surface soil sampling for radionuclides was warranted as well as to provide an initial screening for worker safety during future investigations. Results of the aerial gamma survey and the OU 11 HPGe survey are presented in Figure 2-1 and Table 2-1, respectively.

Exposure rates from the aerial gamma survey were compared to exposure rates from two unrelated HPGe detector system studies. The first HPGe survey was performed as a verification of the aerial data. The second HPGe survey was completed in July of 1993 on a tighter grid for an investigation in the Protected Area. Overlays of the initial HPGe results for areas inside the Protected Area were placed on the aerial gamma isopleth maps to verify results, and the outcomes were nearly identical, the only difference being that the HPGe results were more refined due to the proximity of the instrument to the ground (10 meters for the ground-based system and 46 meters for the aerial unit).

Aerial gamma exposure rates measured at OU 11 are lower than those measured on plantsite and other surrounding areas (11-13 μR/h for OU 11 and 15-17 μR/h for surrounding areas). Figure 2-1 shows gross count exposure rates superimposed on a photograph of the Rocky Flats area (EG&G EM, 1989). The recent HPGe survey shows gamma exposure rates from 5 to 8 μR/h (Table 2-1), which are even lower than the 1989 exposure rates.

Table 2-1 HPGe Survey Results at the West Spray Field

OU-11 Detector 4A6 @ 6.5m

OU	File Name	Station	North	East	K-40	Ra-226	Th-232	U-238	U-235	Cs-137	Am-241	Pu-239	Exposure
			feet	feet	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	nCi/g	uR/h
11	189.chn	I10	749200	2076900	7.76	0.772	1.14	1.72	0.0786	0.497	0	0	6.24
11	190.chn	K10	749000	2076900	7.6	0.812	1.15	2.05	0.0721	0.521	0	0	6.3
11	193.chn	M10	748800	2076900	7.92	0.942	1.14	1.7	0.0528	0.496	0	0	6.54
11	194.chn	O10	748600	2076900	7.83	1	1.22	1.98	0.0583	0.574	0	0	6.8
11	195.chn	W10	747800	2076900	6.01	0.831	0.944	1.59	0.0478	0.581	0.089	0	5.56
11	223.chn	W10	747800	2076900	6.51	0.789	1.03	1.65	0.0759	0.648	0	0	5.79
11	196.chn	U10	748000	2076900	7.04	0.957	1.14	1.91	0.0697	0.667	0	0	6.41
11	199.chn	F30	749500	2078900	7.12	0.959	1.11	1.87	0.063	0.521	0	0	6.42
11	200.chn	F27	749500	2078600	6.15	0.781	0.909	1.41	0.0503	0.445	0	0	5.41
11	201.chn	E24	749600	2078300	7.33	0.856	1.13	2.02	0.0827	0.514	0	0	6.16
11	202.chn	K24	749000	2078300	6.72	0.733	0.956	1.66	0.0614	0.494	0	0	5.54
11	205.chn	N24	748700	2078300	6.29	0.809	0.97	1.43	0.0567	0.565	0	0	5.91
11	206.chn	S10	748200	2076900	7.93	0.959	1.14	1.82	0.0518	0.628	0	0	7.43
11	207.chn	Q10	748400	2076900	5.97	0.659	0.906	1.47	0.0593	0.494	0	0	5.37
11	208.chn	Q12	748400	2077100	6.11	0.646	0.914	1.33	0.0559	0.522	0	0	5.48
11	212.chn	W12	747800	2077100	6.9	0.857	1.05	1.74	0.0685	0.613	0	0	6.08
11	213.chn	U12	748000	2077100	6.53	0.913	1.09	1.79	0.0617	0.67	0	0	6.15
11	214.chn	S12	748200	2077100	6.99	0.908	1.14	1.81	0.0702	0.697	0	0	6.44
11	217.chn	O12	748600	2077100	7.43	0.938	1.23	1.87	0.0642	0.591	0.075	0	6.71
11	224.chn	O12	748600	2077100	7.38	0.849	1.18	1.9	0.0744	0.585	0	0	6.32
11	225.chn	O12	748600	2077100	7.46	0.831	1.2	1.91	0.0765	0.594	0	0	6.36
11	218.chn	M12	748800	2077100	7.43	0.958	1.16	2	0.0719	0.561	0	0	6.63
11	219.chn	K12	749000	2077100	7.1	0.957	1.12	1.93	0.0709	0.533	0	0	6.43
11	220.chn	I12	749200	2077100	7.95	0.991	1.15	1.72	0.0601	0.501	0	0	6.64
11	227.chn	H24	749300	2078300	6.93	0.757	1.07	1.77	0.069	0.591	0	0	5.83
11	228.chn	J25	749100	2078400	7.15	0.777	1.14	1.73	0.0847	0.638	0	0	6.15

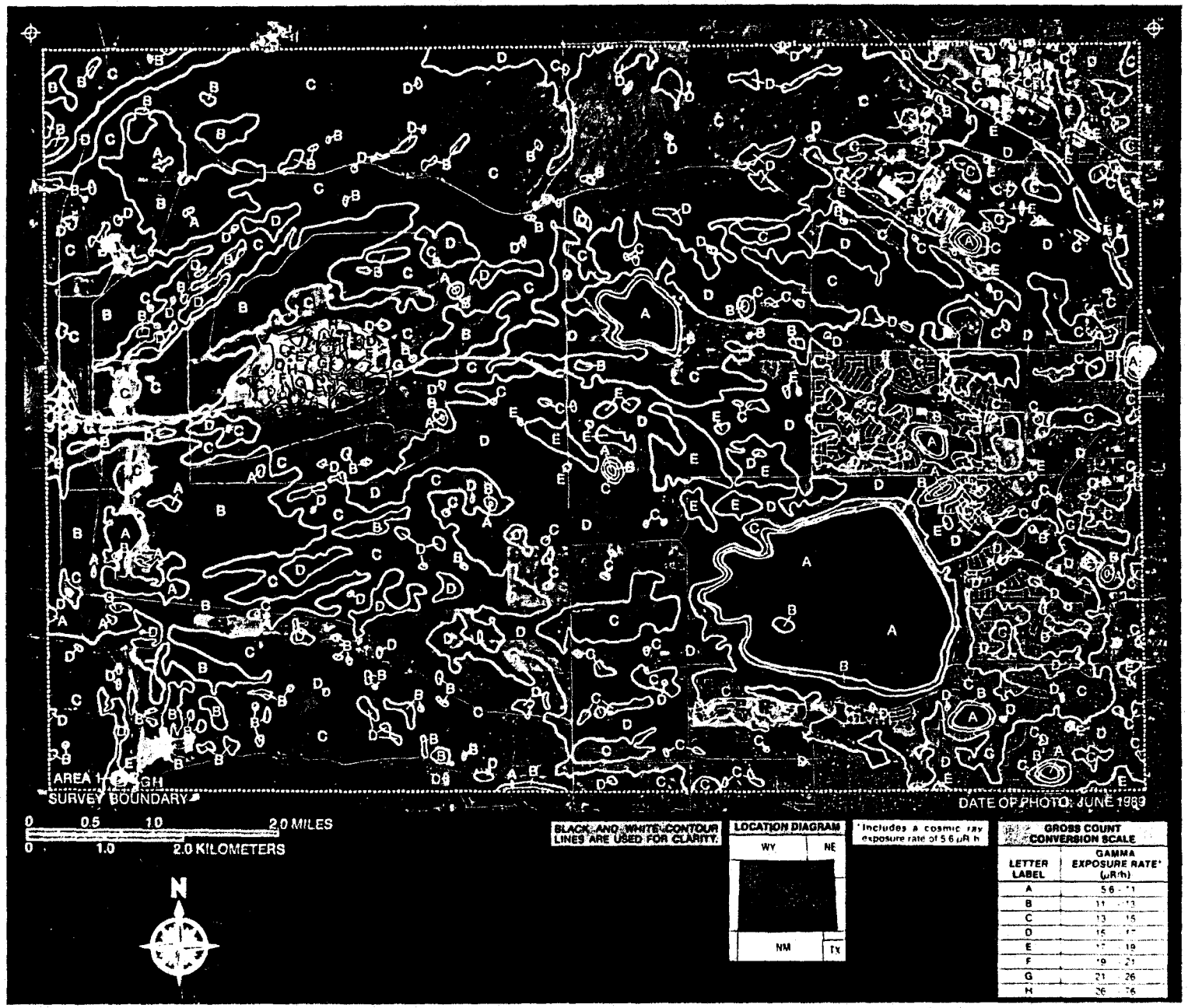


Figure 2-1 *TERRESTRIAL GAMMA RAY EXPOSURE RATE AT 1 METER ABOVE TERRAIN EXTRACTED FROM THE GROSS COUNT RATE DATA*

2.2 SURFACE SOIL SAMPLING AND TEST PITS

In 1986, a soil sampling program was conducted within the boundary of OU 11, but not in any of the areas that received direct application of liquids. Several samples were collected and composites for 0- to 6-inches and 6- to 12 inches of soil were analyzed for metals, inorganic parameters, and radionuclides. Volatile organic compounds were analyzed from surface scrapes. The sampling program determined that spray constituents were present in areas not subject to direct spray application indicating either contamination from other sources or that surface runoff carried potential contamination.

A more extensive sampling program was conducted in 1988 to characterize the entire spray field area. Twelve test pits were excavated at points of maximum expected spray constituent concentrations (spray irrigation runoff channels or surface depressions) and soil samples were collected to a maximum depth of five feet. Thirty-six samples were collected and analyzed for constituents known to have been in the applied liquid including inorganic parameters, radionuclides, volatile organic compounds, lead and mercury. These data provide a much more comprehensive view of the nature of contamination in areas that were both subject to direct spray application and subject to windblown spray and surface runoff. Figure 2-2 shows the locations of the 12 test pits and other historical sampling activities at OU 11.

Because spray application involves quantities spread over large areas in low concentrations, and due to the high evapotranspiration rate in the RFP area, constituent concentrations were anticipated to be higher in surface soils than in subsurface soils or groundwater. Therefore, historical investigations focused on surface and shallow subsurface soil sampling. Soil samples collected during the 1986 program were taken from an area not anticipated to have the greatest potential for contamination from the spray fields; however, the 1988 test pits were generally located in surface channel areas and are therefore believed to represent higher risk areas.

The 1988 samples were taken from test pits exposing the uppermost 5 feet of soil. Layer 1 was compared to surficial soils background data from Rock Creek, because it consisted of the uppermost two feet of soil. Soil layers 2 and 3 were collected from subsurface materials (three to five feet below the surface), and were therefore compared with background data from the

Rocky Flats Alluvium (RFA) in the Geochemical Characterization Report (EG&G 1992b). All analytical data are summarized in Appendix C of this TM.

Radionuclides were analyzed in soil samples collected in 1986 and 1988. Both sampling programs showed levels of uranium-233, 234, uranium-238, and plutonium above the 1989 background (EG&G, 1992b). The 1988 closure plan (Rockwell International 1988a) stated the closure performance standards for uranium and plutonium as being 32 pCi/g and 0.9 pCi/g, respectively. At the time of 1986 sampling, plutonium activities were found to range from 0.00(±0.06) pCi/g to 0.59(±0.06) pCi/g. Although plutonium-239, 240 at a mean activity of 0.1525 pCi/g for 1988 surface samples is significantly above the Rock Creek background activity of 0.0475 pCi/g, it is still well below closure performance standards in the 1988 closure plan. Currently, there is no standard for plutonium for the RFP. Risk-based soil reference levels have been established for OU 3 (Offsite Areas) as 3.5 pCi/g for residential areas and 100 pCi/g for recreational areas (US DOE, 1993). Clearly, the plutonium activities in soil detected in OU 11, although statistically greater than determined background activities, are less than any of the standards adopted for RFP use, including the 1988 West Spray Field closure performance standard. Furthermore, recent ground-based HPGe studies have shown back-calculated activities of plutonium-239 and americium-241 to be below detection levels. Although levels for Uranium were above background in soils, it has been determined that they are not of Rocky Flats origin (Appendix B). The most likely origin for this Uranium is the considerable mining activities (historical and current) upgradient of OU 11.

Several organic compounds included on the Hazardous Substance List, were found in soil samples at concentrations above detection limits. Although these results could be indicative of site contamination, they could also be the result of laboratory contamination. Generally, indication of possible laboratory contamination is provided by comparison with laboratory blanks, but no analyses for laboratory blanks were included with the analytical results for volatile organic compounds for the 1986 and 1988 soil samples. Inspection of the data indicates that the volatile organic compounds are near or below detection limits. It is unlikely the volatile organic compounds in the spray liquid would have been adsorbed onto soil particles because the act of spraying would probably have caused the organic compounds to volatilize and dissipate.

Nitrate was not analyzed in soils during the 1986 program; however, in 1988, sample analyses

indicated concentrations of nitrate (as nitrogen) ranging from non-detect (i.e. below 20 mg/kg) to 150 mg/kg. Most non-detects occurred in the upper layer of the test pits. Results of 420 mg/kg and 110 mg/kg from Area 1 of the spray field were noted in the original lab report as requiring re-analysis (Rockwell International, 1988b). In the zone sampled, there does not appear to be a correlation of nitrate concentrations with depth. The 1988 closure plan set a closure performance standard for nitrate in soil as less than 100 parts per million (Rockwell International, 1988a). As part of a sitewide ecological study, surface soils at the West Spray Field will be sampled for nitrate content. The data will be used in the risk assessment and supporting documents for the OU 11 RFI/RI Report.

In summary, soil analyses collected in 1986 and 1988 from the OU 11 area have the following general characteristics in comparison to Rock Creek background:

- Plutonium activities are greater than background but less than cleanup guidance standards.
- Concentrations of volatile organic compounds are inconclusive because of lab contamination but are at or near the detection levels and as stated earlier, due to the method of wastewater application, VOC's most likely evaporated.
- Nitrate was present above background concentrations in some samples from the 1988 program which targeted locations anticipated to have the greatest contamination.

2.3 GROUNDWATER MONITORING ACTIVITIES

In compliance with RCRA regulations, which require a groundwater monitoring program capable of determining the impact of the RCRA regulated unit on the upper most hydrostratigraphic unit, groundwater monitoring wells were installed. Prior to the 1986 RCRA monitoring program, few wells had been installed; however these have since been abandoned due to incomplete well construction information. No data from the abandoned wells was used for studies in this TM.

Groundwater monitoring at the West Spray Field began routinely in 1986 and is being conducted to provide data for assessment of the level, extent, and migration characteristics of contamination in the upper hydrostratigraphic unit beneath the unit (Rockwell International 1987). Groundwater flow in the upper hydrostratigraphic unit moves in an east-northeasterly direction. The groundwater flow rate was calculated at 28 feet per year in 1991. Fourteen alluvial wells and three bedrock wells are routinely sampled at the West Spray Field. Only the 1986 alluvial wells are screened through the entire thickness of the alluvium. The 1989 wells are screened in the 20-foot interval above bedrock. This arrangement adds uncertainty to the understanding of chemical distribution in the subsurface because the wells screened through the entire interval have higher contamination levels than do those completed only in the lower saturated zone (Section 4.3.3 of this TM explains this situation thoroughly).

Groundwater quality in the upper hydrostratigraphic unit in downgradient wells was statistically compared with that in the upgradient wells and with background groundwater quality (Section 4.2). The only volatile organic compound detected in groundwater was xylene; however, total xylene was only detected in one sample from the fourth quarter of 1992 at a concentration of 10 µg/l. Xylene and other volatile organic compounds were not detected in any other quarter or well in the West Spray Field area.

The radionuclides detected in groundwater included americium-241, plutonium-239,240, uranium-233,234, uranium-238, and tritium. Only americium, plutonium, and tritium were detected at activities exceeding sitewide background levels (for a greater level of detail, see Section 4.1 or Appendix C of this TM). Tritium and americium were each detected at activities above background in two wells during different sampling quarters of 1992.

Plutonium activity was above the sitewide background value in groundwater from only one well during one quarter. Concentrations of uranium-233,234 were detected in five downgradient wells but were within the upper tolerance limits of background values.

The inorganic analytes frequently detected include bicarbonate, calcium, chloride, fluoride, magnesium, nitrate/nitrite, silicon, sodium, sulfate; however, only calcium, chloride, fluoride, silicon, and sodium were measured at significantly greater concentrations in the downgradient monitoring wells. Sulfate, nitrate/nitrite, magnesium and total suspended solids all were measured at higher concentrations in the upgradient monitoring well (Well 5186). This could be due to an upgradient source, gradient reversal due to spraying or perched water moving west due to mounding. This issue is further discussed in Subsection 4.3.3.

In summary, statistical comparisons of upgradient verses downgradient groundwater quality at the compliance boundary of the West Spray Field indicate that this unit may have contributed americium, plutonium, and sodium to the groundwater. The volatile organic compounds are detected at concentrations at or near their detection limits and are typically measured below the detection limit during subsequent analyses.

3.0
DATA QUALITY OBJECTIVES

The Data Quality Objectives (DQO) process, as outlined in Data Quality Objectives Remedial Activities (U. S. EPA 1987), was utilized in developing this technical memorandum. The DQO process ensures that the project objectives are well defined, identifies the environmental data necessary to meet those objectives, and ensures that the data collected are sufficient and of adequate quality for the intended use.

The Field Sampling and Data Collection activities will focus on characterization of the site physical features and the nature of contamination from the source(s), soils, and groundwater in order to determine risk and to develop a CMS/FS or support a Final Action Decision. Definition of site physical features includes a surface radiation survey (previously done for screening as well as scoping purposes), an ecological evaluation (including surface soil samples analyzed for nitrates), and bore hole and monitoring well installation. These assessments will determine the need for remediation and will be used to evaluate remedial alternatives, if necessary, as well as satisfy the five general goals of an RFI/RI (U. S. EPA, 1988a):

1. Characterize site physical features;
2. Define contaminant sources;
3. Determine the nature and extent of contamination;
4. Describe contaminant fate and transport; and
5. Provide a baseline risk assessment (if necessary).

DQOs are qualitative and quantitative statements that specify the quality and quantity of data required to support the objectives of the RFI/RI (U. S. EPA, 1987). The DQO process is divided into three stages:

Stage 1 - Identify decision types;
Stage 2 - Identify data uses/needs; and
Stage 3 - Design data collection program.

Through application of the DQO process, site-specific goals were established for the investigation and data needs were identified for achieving those goals. This section of the TM

discusses the DQO process specific to the West Spray Field.

Data collected during previous investigations were used to develop the DQOs. Previous data collection activities focused on site characterization rather than performing a quantitative risk assessment or environmental evaluation. The historical data is summarized in Section 2.0 (Previous Investigations) of this TM. Section 2.0 also presents rationale used in identifying OU 11 data needs.

3.1 STAGE 1 - IDENTIFY DECISION TYPES

Stage 1 of the DQO process identifies the decision makers, data users, and the types of decisions made as part of the RFI/RI process (Table 3-1). The information is then used to identify the data needs and objectives. The following paragraphs discuss in more detail the identification of data users, development of the conceptual model and the resulting data objectives and decisions for the OU 11 RFI/RI investigation.

Table 3-1 Decision Types, Makers, and Data Users for the OU 11 RFI/RI Process

DECISIONS	DECISION MAKERS	DATA USERS
1. Is surface Contamination high enough to require further investigation?	CDH, EPA DOE Project Manager EG&G Project Manager	Statisticians Risk Assessors
2. Have ecological receptors been adversely affected?	CDH, EPA DOE Project Manager EG&G Project Manager	Ecologists Risk Assessors
3. Does a perched water system exist with accumulated contamination?	CDH, EPA DOE Project Manager EG&G Project Manager	Geologic/Hydrogeologic Modelers Field Geologists
4. Is the vadose zone contaminated?	CDH, EPA DOE Project Manager EG&G Project Manager	Risk Assessors Statisticians Geochemists
5. Is there a complete pathway for downward migration?	CDH, EPA DOE Project Manager EG&G Project Manager	Modelers Geologists Hydrogeologists Geophysicists

3.1.1 Identify and Involve Data Users

Data users are divided into three groups: decision makers, primary data users, and secondary data users. The decision makers for OU 11 are personnel from EG&G, DOE, EPA, and CDH. These personnel are responsible for decisions related to management, regulation, investigation, and remediation of OU 11. The decision makers are involved through the review and approval process specified in the IAG. Primary data users are individuals involved in ongoing RFI/RI activities for OU 11. These individuals are the technical staff of CDH, EPA, DOE, EG&G, and EG&G subcontractors. Primary data users include geoscientists, statisticians, risk assessors, engineers, and health and safety personnel. The primary data users will be involved in collection and analysis of data and in preparation of the RFI/RI report, including the Baseline Risk Assessment. Secondary data users are those users who rely on RFI/RI outputs to support their activities and may include personnel from CDH, EPA, DOE, EG&G, and EG&G subcontractors working in areas such as data base management, quality assurance, records control, and laboratory management.

3.1.2 Evaluation of Available Data

The historical investigations conducted at the West Spray Field and associated areas of OU 11 have generated data which were evaluated for completeness and used in identifying current data gaps. The previously collected data, its application to this FSP, and its quality and useability are extensively described in Section 2.0 (Previous Investigations) of this TM. The majority of data gaps exists in the area of shallow groundwater, so the DQOs and this investigation will focus on that media. The following list of historical and recently collected data were used to evaluate conditions at the West Spray Field and make determinations as to the necessary extent of further investigations:

- historical and current monitoring well analytical data
- 1986 surface soil sampling results
- 1988 surface and subsurface soil sampling results
- historical and recent surface water analyses
- radiological screening (aerial and ground-based)

3.1.3 Conceptual Site Model

The function of the West Spray Field conceptual model is to describe the site and its environs and to present hypotheses regarding contamination (or potential contamination), routes of migration, and potential impact on receptors. The original Phase I RFI/RI Work Plan for OU 11 presents a conceptual model that includes a description of the contaminant source, release mechanisms, transport medium, contaminant migration pathways, exposure routes, and receptors. The Hydrogeologic Conceptual Model (Figure 3-1) takes the modeling process one step further by presenting potential migration pathways in a geologic setting. The primary release mechanisms for contaminants from the West Spray Field are fugitive dust, surface-water runoff, infiltration and percolation of groundwater, bioconcentration/bioaccumulation, and tracking. The possible exposure pathways for contaminants resulting from spray application include ingestion, inhalation, and dermal contact involving contaminated soil, groundwater, and surface water.

Surficial and shallow soils, which received waste water through direct application and surface runoff, are recognized as the primary media of concern for potential contamination, although historical analytical results show most contaminant concentrations in these media to be below background levels (Section 4.2). Soil characterization activities and recommendations relative to previously collected data are presented in Sections 2.0 (Previous Investigations) and 4.0 (Sampling and Analysis Plan) of this technical memorandum. The subsurface soils will be characterized further by borehole sampling during drilling activities to install monitoring wells. If significant levels of contamination are found, further investigation will be necessary and a soil sampling program will be initiated in accordance with a statistical sampling grid of biased and random locations (EG&G 1993a).

Due to data gaps in groundwater investigations at OU 11, this is the media that will be examined most thoroughly. Specifically, the potential for a perched water system to exist and accumulate contaminants will be investigated.

Hydrogeologic Conceptual Model

The primary goal of the field sampling plan is to evaluate current contamination levels as these relate to the potential for migration of contaminants from the unsaturated zone into the saturated zone of the water table aquifer. Previous soil and groundwater investigations do not indicate that significant levels of contamination exist in OU 11 (See Section 2.0). Data collected from wells constructed to evaluate only the saturated zone of the uppermost hydrostratigraphic unit indicate that concentrations for individual contaminants are insignificant. However, elevated levels of some contaminants, specifically nitrates, have been detected in wells which were screened to evaluate the entire (saturated and unsaturated) uppermost hydrostratigraphic unit at OU 11, including the saturated and unsaturated zones. It is hypothesized that these elevated levels are the result of the contribution of contaminated perched groundwater mounds to the overall shallow groundwater system. (Evidence for perched groundwater conditions is discussed in Section 4.3.3.1.) To date, characterization of shallow subsurface lithologies and water chemistries is incomplete. The revised field sampling plan is designed to test the hypothesis that perched groundwater mounds exist and to characterize shallow subsurface lithologies and groundwater chemistry for significant levels of contamination. If significant levels of contamination are found, then further vadose zone characterization will be considered to further analyze the migration of contaminated groundwater as a source of significant risk. If no significant levels of contamination are found to exist in shallow perched groundwater mounds, then no further characterization of the groundwater system will be deemed necessary.

At the West Spray Field, the uppermost hydrostratigraphic unit is the Rocky Flats Alluvium, a heterogeneous alluvial fan deposit consisting of unconsolidated gravels, sands, and clays with the water table at a depth of approximately 50 feet. However, as previously discussed, the probable existence of groundwater mounds in the vadose zone constitutes the primary concern relative to potential groundwater contamination. The following conceptual model for shallow groundwater mounding is proposed as a hypothesis to be evaluated: Spray application of water occurred during several years as a waste management activity; surface runoff, evapotranspiration, and infiltration occurred during that time; infiltrated water recharged the alluvial hydrostratigraphic unit to a small extent, but also mounded over semi-pervious clay layers or lenses of lower vertical hydraulic conductivity; finally, when spraying ceased, perched zones began to diminish due to continued vertical migration and evapotranspiration. Contaminants may still exist in these perched zones either as dissolved constituents or precipitates.

Historical water level data and recent drilling reports indicate that perched water conditions probably exist under portions of OU 11. Evidence for perched conditions is discussed in Section 4.3.3 where the justifications of monitoring well locations are presented. If groundwater has become contaminated to significant levels above background because of spray application, perched water, by virtue of its proximity to the surface of application, would have the potential for containing maximum levels of contamination. The migration of perched groundwater would constitute a potential health risk. Figure 3-1 is a schematic representation of the vadose zone and groundwater mounds associated with spray application. To date, the characterization of vadose zone geology and water chemistry is incomplete. As previously mentioned, most monitoring wells in the West Spray Field were designed to monitor the saturated zone of the uppermost hydrostratigraphic unit. In addition, because of the presence of large cobbles and boulders in the alluvial gravels, most of these wells were drilled using percussion technology. Lithologic descriptions of the collected cuttings lack accuracy and detail. Therefore, for this investigation, subsurface lithologies as well as bore hole and groundwater chemistries will be characterized (in accordance with Section 4.2, Contaminants of Concern). Seismic data (Figure 3-1) was not utilized for the selection of the drill sites. However lithologic data collected from the field sampling plan will be used as a aid in calibrating the seismic data to the subsurface geology.

Mathematical Modeling of Shallow Perched Groundwater Mounds

For planning purposes, preliminary mathematical analytical modeling was performed. Using a method documented by Brock (1976), a hypothetical two dimensional mound profile under WSF Spray Area One was calculated. Appendix B shows the model calculations used to predict mound height and extent. Parameters used in the model were in accordance with field data collected in other areas of RFP and professional judgement. Hydrologic assumptions relevant to the model are similar to those inherent in various groundwater models and are explicitly stated. This model was specifically used to provide a rough "order-of-magnitude" analysis of anticipated perched groundwater mound height.

Modeling results suggest that perched mounds resulting from spray application are relatively thin, with the calculated steady state mound height under Spray Area One being approximately seven feet. The significance of presenting this information is to emphasize the importance of

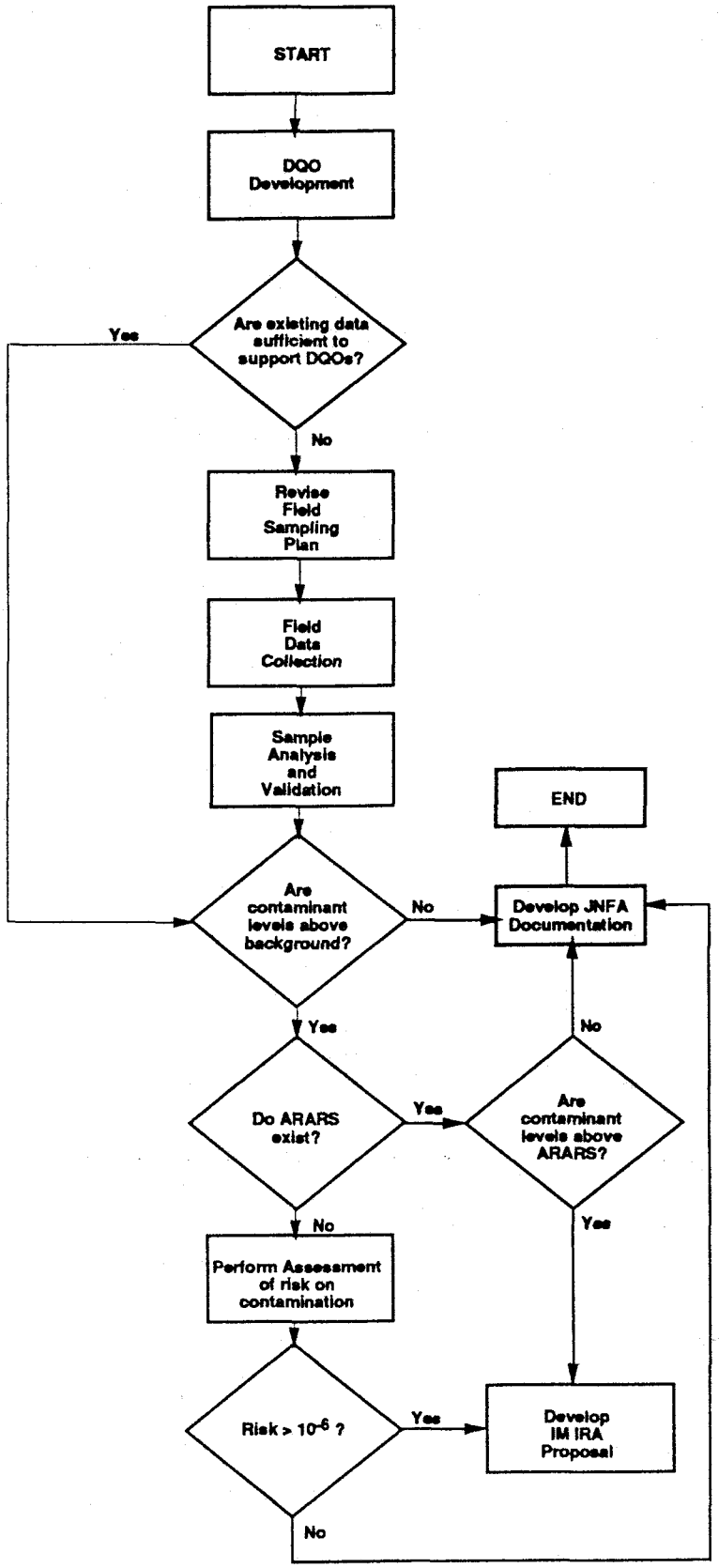
core recovery and data collection during drilling activities. The zone of interest is thin; therefore appropriate drilling and sampling technologies must be used to ensure adequate sample recovery. Often sample recovery in coarse grained alluvial soils is poor when conventional coring techniques are employed and thin zones of interest might not be represented. A discussion of drilling and sampling techniques for the OU 11 sampling plan is presented in Section 4.0.

3.1.4 Objectives of the Revised Field Sampling Plan

The main objective of this TM is to collect adequate field data to support a final action decision for OU 11. This investigation will be based on the process flow diagram (Figure 3-2). The field investigation will be conducted as follows:

- Evaluate current and historical data collected for surficial soils within OU 11;
- Assess current ecological conditions at OU 11;
- Investigate the possibility of contamination within the vadose zone at OU 11;
- Determine if a zone of perched water exists at OU 11 and if so, whether contaminants have accumulated in that zone and;
- Determine if a potential for a complete pathway for downward migration exists.

FIGURE 3-2: PROCESS FLOW DIAGRAM



3.2 STAGE 2 - IDENTIFY DATA USES AND DATA NEEDS

Stage 2 of the DQO process involves the identification of data uses and types as well as data quality and quantity needed to meet the objectives specified in Stage 1. It also includes the selection of the sampling approach and analytical options for the RFI/RI investigation. Finally, DQOs must address the precision, accuracy, representativeness, comparability, and completeness (PARCC) parameters of the planned activities (U. S. EPA 1987).

3.2.1 Data Uses

To address the objectives outlined in Stage I of the DQO process, the anticipated uses for the collected data must be specifically stated. The data from the Revised Field Sampling Plan field investigation will be used to assess whether significant contamination exists in the vadose zone beneath OU 11, and if it exists, evaluate the vertical and horizontal extent of the contamination and potential for risk to human health and the environment.

The three categories for data uses as defined by the EPA (U. S. EPA 1987) that apply to OU 11 revised field sampling plan activities are health and safety, site characterization, and risk assessment. Data from previous investigations were used to determine that immediate risk to public health was minimal. Therefore, initial screening data will be used for worker health and safety purposes and the data gathered from the investigation outlined in this field sampling plan will be used for site characterization and risk assessment simultaneously.

3.2.2 Data Types

Following identification of the intended users (Section 3.1) and use of the data to be collected, the necessary data types were developed. Data types include general categories such as water quality data and groundwater level data, as well as more specific information such as proposed analytical parameters.

Specific types of data to be collected during implementation of the Revised Field Sampling Plan

investigations include stratigraphic, groundwater chemistry, soil chemistry, physical soil property, and surface radiation survey data. Some of the data has previously been collected for the purpose of determining whether interim measures need to be taken to prevent further contamination. New data will be gathered and historical data will be examined through the following efforts;

- Two surface radiation surveys and two surface soil analyses were previously performed for screening and scoping purposes. An aerial gamma survey was performed in 1989, and a limited ground-based radiation survey was performed in September of 1993. Data from both will be used to fill in data gaps for surface soils. The surficial soil analyses were conducted in 1986 and 1988 and data from these investigations will be statistically evaluated against background values and risk parameters. These types of data are needed to determine the level of safety for workers as well as to evaluate the need for further surface soil analyses.

- The Environmental Evaluation will be performed to determine the nature and extent of present and potential impacts of OU 11 contaminants on biota. As part of a site-wide study and in conjunction with this EE, nitrates in surface soils will also be analyzed. The EE will be performed in two phases with the Effects Assessment performed first, and the Exposure Assessment performed based on results of the Effects Assessment. If results from the Effects Assessment prove no significant effects on the ecology at OU 11, the Exposure Assessment will not be necessary.

- A bore hole drilling and groundwater monitoring program will be implemented to acquire additional soil chemistry and groundwater data in strategic locations. Soil chemistry data will be collected near the surface and throughout the vadose zone to better characterize spatial distribution of constituents of concern. In addition, physical properties of soil will be examined to better refine the conceptual model. After the bore holes are drilled to obtain alluvium samples, they will either be completed as monitoring wells targeting specific areas of lithologic interest or abandoned as per Section 4.3.3.2 of this TM. The additional soil sample analyses and groundwater sample analyses, in conjunction with the pore-water sample analyses will aid in characterizing the nature and extent of contamination within the vadose zone.

3.2.3 Data Quality

To address the objectives outlined in Stage 1 of the DQO process, the anticipated uses for the collected data are specifically stated. Data quality has been specified through the listed analytical levels on Table 3-2. Data gaps have been identified in the definition of site physical features and can be satisfied through the efforts of (1) a surface radiation survey and evaluation of historical surficial soil analytical data, (2) an ecological evaluation, and (3) bore hole drilling followed by monitoring equipment installation. Table 3-2 describes the use and level of data to be collected in this field effort.

Table 3-2
Objectives and Activities of the Revised Field Sampling Plan

Objective	Field/Analytical Activity	Analytical Level*	Data Use
Determine if Contamination Exists in the Vadose Zone	1) Collect and analyze soil samples from bore hole core 2) Install monitoring wells targeting suspected areas of perched groundwater 3) Determine total drilling depth and abandon when installation of monitoring wells is deemed inappropriate	I & II - Field IV & V - Analytical I & II - Field IV & V - Analytical II - Field IV - Analytical	Site characterization Risk assessment Field Decisions
Evaluate Current Radiological Screening of Surface and Subsurface Soils	1) Obtain recent HPGe Survey data & evaluate against 1989 aerial survey 2) Statistically evaluate 1986 and 1988 surface and subsurface soil investigation results	II - Field IV - Analytical	Site characterization Risk assessment Health and Safety
Assess Current Ecological Conditions	1) Compare current conditions to backgrd 2) Determine the absence or presence of adverse impacts to the ecology.	Not Applicable	Site characterization Risk assessment

* Level I - Field analysis with portable instruments
Level II - Field analysis with mobile lab or more sophisticated equipment than level I
Level III - Analyses performed in an off-site lab
Level IV - Contract Lab Program (CLP) routine analytical services
Level V - Analysis by non-standard methods

3.2.4 Data Quantity

Data quantities sufficient to support the DQOs are detailed in Section 4.0, Sampling and Analysis Plan and justified in Sections 2.0, Assessment of Existing Data and Subsection 4.2, Contaminants of Concern. Essentially, the data quantity required is that which determines if perched zones exist, and if so, whether or not contaminants occur in those perched zones at levels which present risk to human health or the environment. The amount of data needed to support the Baseline Risk Assessment and subsequent RFI/RI Report is discussed and defended in Sections 3 and 4 of this TM.

3.2.5 PARCC Parameters

PARCC parameters for analytical Levels I, II, IV, and V are discussed below. Goals for precision, accuracy and completeness are specified in the Quality Assurance section (Section 5.0) of this Work Plan.

Precision is a quantitative measure of data quality that defines the reproducibility or degree of agreement among replicate measurements of a single analyte. The closer the numerical values of the measurements are to each other, the more precise the measurements. Precision will be determined from the results of duplicate analyses (EG&G, 1991a).

During the collection of data using field methods or instrumentation, precision is checked by reporting several measurements taken at one location and comparing the results. Sample collection precision shall be measured in the laboratory with the analysis of field replicates and laboratory duplicates (EG&G 1992c). Analytical precision will be achieved by adhering to the analytical methods contained in the GRRASP (EG&G 1990). Sampling precision will be achieved by conformance to the procedures specified in the Environmental Management Division's Operating Procedure manuals referenced above.

Accuracy will be expressed in terms of completeness and bias. Accuracy is a quantitative measure of data quality that refers to the degree of difference between measured or calculated values and the true value. The closer to the true value, the more accurate the measurement.

One of the measures of analytical accuracy is expressed as a percent recovery of a spike or tracer that has been added to the environmental sample at a known concentration before analysis (EG&G, 1991a). Although it is not feasible to totally eliminate sources of error that may reduce accuracy, error will be minimized by using standardized analytical methods and field procedures.

Representativeness is a qualitative parameter that expresses the degree to which sample data accurately represent a characteristic of a population, parameter variations at a sampling point, or an environmental condition (EG&G, 1992c). Representative data will be obtained by analyzing historical data, determining data gaps, and implementing a field sampling plan that completes data necessary for characterization. Fieldwork will be conducted according to SOPs, further aiding the collection of representative data.

Completeness is a quantitative measure of data quality expressed as the percentage of valid or acceptable data obtained from a measurement system. Completeness is achieved by obtaining samples for all analyses required at the each sampling location, providing sufficient sample material to complete those analyses, and producing QC samples that represent all possible contamination situations such as potential contamination during sample collection, transportation, or storage (EG&G, 1992c).

Comparability is a qualitative parameter describing the confidence with which one data set may be compared to another (U. S. EPA, 1987). The standard laboratory methods of the GRRASP (EG&G 1990) and standard operating procedures for conducting field work will allow for one to one comparability of OU 11 RFI/RI data to other work conducted in conformance with those same standards.

3.3 STAGE 3 - DESIGN DATA COLLECTION PROGRAM

Stage Three of the DQO process compiles the various elements of Stages One and Two into a cohesive data collection program. A Sampling and Analysis Plan and Quality Assurance/Quality Control Plan have been developed and are included as Sections 4.0 and 5.0, respectively, of this Technical Memorandum.

4.0
SAMPLING AND ANALYSIS PLAN

4.1 OBJECTIVES AND APPROACH

The objective of this field sampling plan is to provide the scope for additional data necessary to complete sufficient characterization of the West Spray Field that will be used to evaluate the potential risk from the site. The RFI/RI Report and risk assessment for OU 11 require adequate data coverage of the area. Identification of data gaps was determined by assessing historical data, performing preliminary investigations (i.e. the ground-based radioisotope survey), and determining parameters needed to fully evaluate contamination pathways. All data incorporated into this document was subject to QA testing and rigorous statistical analysis using the Gehan method. Each section provides justification for locations, amounts, and types of sampling, including process knowledge of solar pond water constituents, known locations of areas that received maximum spray, and geologic modeling information.

4.2 CONTAMINANTS OF CONCERN

Contaminants of Concern (COC) for any given site are determined for each affected medium. Contaminants of similar chemistry are grouped into analytical suites. Typical suites include volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), pesticides, radionuclides, metals and water quality parameters. Using EPA guidance, the examination of contaminant concentrations determines whether or not the contaminant is present in concentrations high enough to pose a potential hazard to human health or the environment. The examination process begins with a long list of analytes that are singularly eliminated or retained after evaluation of 1) background concentration comparisons, 2) detection frequency, 3) essential nutrients, and 4) likely Applicable or Relevant and Appropriate Requirements (ARARs)/Preliminary Remediation Goal (PRG) comparison. Process knowledge and physical features of potentially contaminated areas are also taken into account for COC determinations. This process has been performed and has resulted in a list of the potential contaminants of concern for OU 11.

Sampling of OU 11 media began routinely in 1986 for a variety of analytical suites. An evaluation of suites and media sampled is summarized in Table 4-1. Raw data were screened and certain data points were rejected prior to the evaluations described above. Data points rejected during quality assurance testing were excluded, as well as all data points that did not have qualifiers indicating that they were target data with a quality control designation as "real" (e.g., those data points that were spikes, blanks, surrogates, etc.). These suites and media were considered the initial point for the current evaluation of potential contaminants of concern (PCOCs).

Table 4-1
Analytical Suites and Sampled Media for OU 11

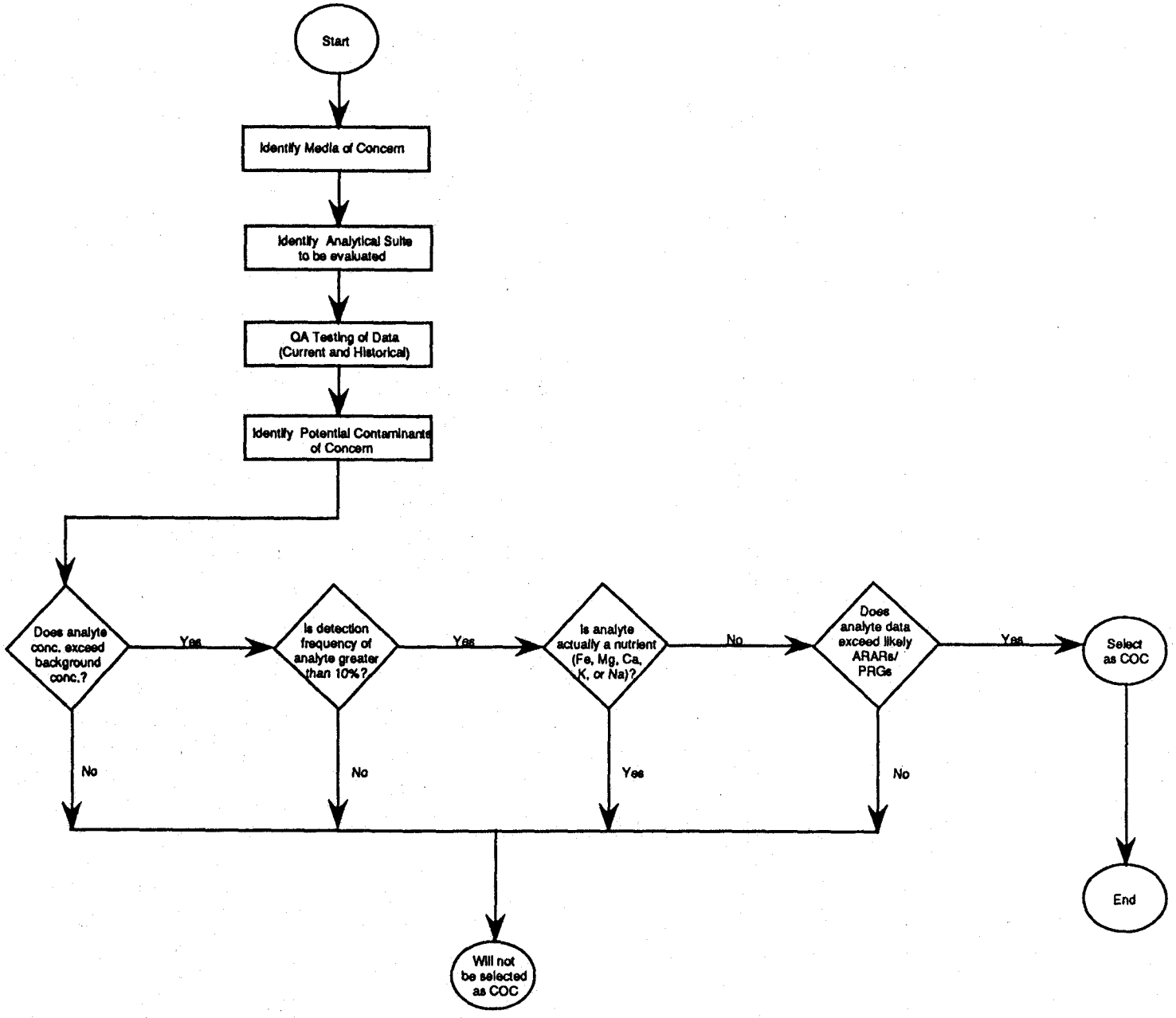
	VOCs	SVOCs	Pesticides and PCBs	Metals	Radio-nuclides	Water Quality Parameters
Surface Water	X	X	X	X	X	X
Groundwater	X			X	X	X
Surface Soil*				X*	X*	X*
Subsurface Soil*				X*	X*	X*

*The subsurface soil contaminants consist of the following nine individual analytes taken from the metals, radionuclides, and water quality suites: gross alpha, gross beta, plutonium-239/240, uranium-233/234, uranium-238, lead, mercury, nitrate/nitrite, and total organic carbon.

4.2.1 Method of Evaluation

An explanation of the method of evaluation as graphically represented in Figure 4-1 is necessary. Analytical results are first compared to background concentrations at the Rocky Flats Plant as presented in the Background Geochemical Characterization Report (EG&G, 1992c), and explained further in this section. If the detection frequency of PCOCs that exceed background is below 10%, they are excluded from the PCOC list. The remaining analytes that are essential nutrients are not considered for the PCOC list. Those still remaining are compared to most likely ARARs or PRGs if ARARs do not exist or if PRGs are more conservative. Finally those that exceed likely ARARs or PRGs are selected as PCOCs. The following sections (or subsections) detail each step in this process.

Figure 4-1 Evaluation of Contaminants of Concern



Background Comparison

A nonparametric statistical comparison (one that does not require assumptions about specific distribution) was performed between the existing OU 11 data and background data obtained from the Background Geochemical Characterization Report (EG&G, 1992c). This was done for the purpose of statistically determining whether the OU 11 data significantly exceeded background data at the 95 percent confidence level (the significance level for determining if the null hypothesis should be rejected is 5 percent). The Gehan test was used, and comparisons were done without data replacement.

During the interagency meeting held on September 29, 1993, EG&G and DOE proposed a modified "Gilbert methodology" for performing OU versus background comparisons to generate a single list of PCOCs to be used for all facets of the OU study. The Statistical Applications Group (SA) from EG&G indicated that some of the battery of statistical tests discussed in Dr. Gilbert's report (i.e., quantile test, slippage test, t-test) may not offer much, if any advantage over the Gehan test alone. Statistician Dr. Kenny Crump made a similar evaluation at the request of EG&G and concluded that the Gehan test alone is sufficient for determining PCOCs (Crump 1993). SA personnel also indicated that these additional tests could be performed simultaneously while the Gehan test was being run. Whether or not these additional tests would indicate PCOCs not recognized by the Gehan test would be examined with the expectation that this would occur only rarely. If this were in fact the case, then the other tests might eventually be eliminated from the battery of tests required.

Currently, the quantile test, slippage test, and t-tests are being performed for OU 11. If a significant difference to the results in the Gehan test is revealed by the additional tests, then the appropriate PCOCs will be added to the list for investigation. Results from the additional tests will be added as an appendix to this TM.

Also agreed to at the September 29 meeting was the use of the 99/99 upper tolerance limits (UTLs) as a "hot-measurement" test. All data from the OU will be compared to the corresponding UTLs to flag any concentrations higher than the appropriate UTL. These flagged data will then be evaluated spatially and temporally, in an effort to locate potential "hot spots" within the OU. The UTL comparison is currently being performed for the OU 11 data and will be incorporated as an appendix to this TM. If hot spots are revealed, this TM will be revised to

incorporate activities that investigate the anomalies. However, due to the nature of the historical treatment of waste at OU 11, no "hot spots" are anticipated. Water from the solar ponds was uniformly sprayed over the spray areas of the West Spray Field, thus the potential contamination should also be rather uniformly distributed across the OU. Because there are no buried drums or other sources that could contribute to potential hot spots, the UTL analysis should provide final proof that no hot spots exist.

Background concentrations were determined for each contaminant in each medium. The background concentrations used for surface soil contaminants were derived from the composited results of nine surface soil samples from Rock Creek. The background concentrations for subsurface soil contaminants were calculated from analytical data for the Rocky Flats Alluvium bore hole materials (EG&G, 1992b). For a statistical comparison of groundwater constituents, alluvial and bedrock groundwaters were considered independently. For alluvial groundwater, the background concentrations were derived from a composite of samples from Wells B200589, B200689, B200789, B200889, B400189, B400289, B400389, B400489, and B405586. For bedrock groundwater, the background concentrations were derived from a composite of samples from Wells B203789, B203889, B203989, B204089, B204189, and B204689. For surface water, the background concentrations used for comparison were a composite of samples from three stations: SW080, SW104, and SW108. Analytes with concentrations at OU 11 below those of background at the 95% confidence level were not considered to be PCOCs.

Statistically derived P-Values were computed in the comparison of OU 11 data to corresponding background values. A P-Value of less than or equal to 0.05 indicates that the analyte concentration in the OU 11 sample is statistically significantly different from that of background; a P-value of greater than 0.05 indicates that the analyte concentration is not significantly different from background at the 95 percent confidence level. The metals that were identified as having concentrations exceeding background concentrations at a 95 percent significance level continued through the process of PCOC determination.

Nutrients Exclusion

Analytes that are common nutrients were excluded in accordance with EPA guidance, which eliminated iron, magnesium, calcium, potassium, and sodium. In addition, silicon is eliminated

in this evaluation as a non-toxic major constituent of soil.

ARAR and PRG Comparison

Both likely ARARs and toxicity-based PRGs were considered in the evaluation leading to the selection of contaminants of concern. ARARs were used to assess water contaminants and PRGs were used to evaluate soil contaminants, except where regulatory guidance existed, in which case, the regulatory guidance was used for comparison. An explanation of how PRG values were calculated is included as Appendix D of this Technical Memorandum.

Because the consideration of toxicity is not applicable to most of the water-quality parameters, they will not be subjected to the above analysis, but are nonetheless retained as a valid analytical suite for further evaluation. However, the following five water-quality analytes will be evaluated with respect to ARARs and PRGs: chloride, fluoride, nitrate/nitrite, sulfate, and cyanide. These were chosen due to process knowledge of solar pond inputs and will undergo the comparative analysis along with analytes from the other suites. If these five analytes and all other suites are eliminated through the evaluation process, the entire water-quality suite will also be eliminated.

4.2.2 Evaluation Results by Media

Alluvial Groundwater

Table C-1 in Appendix C shows the selection process of PCOCs for alluvial groundwater. Metals, radionuclides, and water quality parameters that have been analyzed as part of the RCRA Groundwater Assessment Program are listed. CLP VOCs were analyzed in alluvial groundwater samples but not detected, and are therefore not included in the table. Furthermore, as explained earlier in this Technical Memorandum, VOCs would have volatilized during spray application.

Analytes were first compared against background using the P-Value as discussed above. The following 13 analytes significantly exceeded background values and were retained in the PCOC selection process.

- total aluminum
- total iron
- total manganese
- total sodium
- dissolved mercury
- dissolved silicon
- dissolved sodium
- dissolved gross alpha
- dissolved uranium 233,234
- dissolved uranium 238
- chloride
- fluoride
- cyanide

A review of detection frequencies caused cyanide to be deleted from the list of PCOCs. Iron and sodium were excluded from further consideration because they are essential nutrients. Silicon was eliminated because it is a nontoxic constituent of soil and a major element of the earth's crust. Gross alpha was not further evaluated because it is an indicator of total activity and is not an actual analyte. The list was reduced to the following seven analytes for comparison against likely ARARs and PRGs:

- total aluminum
- total manganese
- dissolved mercury
- dissolved uranium-233,234
- dissolved uranium-238
- chloride
- fluoride

Mercury, chloride, and fluoride were deleted after comparison to likely ARARs and PRGs. Uranium isotope ratios in subsurface soils were compared to discern the source of uranium. The uranium present in subsurface soils was identified to be natural uranium and not contamination form enriched uranium used at the RFP. A discussion of this evaluation and the

significance to OU 11 is presented in Appendix A.

The final list of PCOCs was reduced to aluminum and manganese. However, because significantly high values of aluminum and manganese were indicated only in total sample types and not in filtered samples, those values are due to the fact that aluminum and manganese are major constituents of rock and clay. Unfiltered samples are impacted by turbidity, potentially due to drilling activities and can therefore reflect high values of naturally occurring analytes. The filtered values are a more accurate indication of groundwater quality, and concentrations for aluminum and manganese in filtered samples are not statistically different than background values. Thus, aluminum and manganese will not be included as PCOCs.

Bedrock Groundwater

Table C-2 in Appendix C shows the selection process of PCOCs for bedrock groundwater. All analyzed metals, radionuclides, and water quality parameters are listed. CLP COCs were analyzed in bedrock groundwater samples but not detected, and are therefore not included on the table.

Analytes were first compared against background. The following three analytes significantly exceeded background values and were retained in the PCOC selection process.

- total barium
- total chromium
- dissolved vanadium

A review of detection frequencies and essential nutrients did not alter this list. The list was compared against ARARs and PRG and all analytes were deleted. No PCOCs were identified for bedrock groundwater.

Surface Water

Table C-3 in Appendix C shows the selection process of PCOCs for surface water. All analyzed metals, radionuclides, and water quality parameters are listed. CLP VOCs, CLP SVOCs, and CLP pesticides were analyzed but not detected in surface water, and are therefore not included on the

table.

Sodium exceeded background values. Sodium is an essential nutrient and was excluded from the list. Therefore the surface water medium does not have any PCOCs.

Surface Soils

Table C-4 in Appendix C shows the selection process of PCOCs for surface soils. All analytes from surface soils are listed. None of the analyte values exceeded background; however, comparison of mercury to background was not appropriate because mercury was not detected in background samples. Mercury was further evaluated against likely ARARs and PRGs and eliminated as a PCOC on the basis of comparison to the PRG.

Subsurface Soils

Table C-5 in Appendix C shows the selection process of PCOCs for subsurface soils. The appropriate analytes are listed. Concentrations of plutonium, uranium, lead, and nitrate/nitrite in subsurface soils significantly exceeded background concentrations. These analytes were detected frequently enough to warrant further evaluation and none were essential nutrients. A comparison with ARARs and PRGs eliminated all of these from further consideration. No analytes in subsurface soil are retained as PCOCs in accordance with this evaluation method.

4.2.3 Summary and Conclusions

The evaluation to identify potential contaminants of concern includes selection of analyte suites, data validation, comparison to background concentrations, elimination of nutrients, and comparison with likely ARARs and PRGs. After a thorough statistical evaluation to determine appropriate contaminants of concern for OU 11, the resulting analyte list for each medium identified at OU 11 is as follows:

Groundwater (alluvial):

None

Groundwater (bedrock):

None

Surface Water:

None

Surface Soil:

None

Subsurface Soil:

None

Because PCOCs were determined from monitoring wells designed to evaluate contamination in bedrock groundwater, the list of PCOCs for that medium is appropriate. However, the current conceptual model includes the presence of perched water within the subsurface soil. If this water is encountered during the proposed drilling program, wells will be installed and samples will be analyzed to determine if contamination exists in the perched zone. A list of analytes of concern based on process knowledge and sample data from the few wells with extensive screened intervals has been developed to isolate and analyze water quality from the potential perched system.

Process knowledge, historical analyses of solar pond water, and standards for sampling constituents provided the data needed to determine a PCOC list for the potential perched water zones. Treated sanitary effluent was the major water source for the solar ponds, so nitrate will be the priority contaminant for analysis. Historical analyses of solar pond water indicate low

concentrations of radionuclides in the ponds (EG&G 1993b), therefore, an analysis for radionuclides will be included. Finally, analyzing for TAL metals is standard and would be prudent for complete analytical characterization, thus TAL metals will be included as the last priority in the list of PCOCs for perched water if it exists at OU 11. This list and sampling priority is summarized below:

Priority	Analyte	Logic
1	Nitrates	Process knowledge demonstrates that nitrates were a major constituent of spray water, and nitrates exist at varying levels in different wells at the West Spray Field.
2	Radionuclides	Historical analyses of solar pond water showed low concentrations of radionuclides.
3	Target Analyte List Metals	TAL metals are included for a more complete analysis.

The preceding analysis performed for determining the contaminants of concern for subsurface soils was based on the data collected during the 1986 and 1988 soil sampling programs. For subsurface soil data, the samples were collected from the upper five feet of soil. It is felt that chemical analyses of the upper five feet do not adequately represent the chemical characteristics of all subsurface soils. The likelihood of contaminants of concern being different for deeper soil than near-surface soil is low because the contamination would have to have passed through the upper five feet; however, in order to acquire additional data for characterization purposes, the proposed drilling program will include chemical analyses of the recovered core for the constituents listed below.

- Target Analyte List Metals
- Uranium 233/234, 235, and 238
- Plutonium and Americium
- Nitrate

To summarize, after evaluations of statistical analysis and geologic reasoning, the final list of COCs is as follows:

Groundwater (alluvial):

- Nitrate
- Radionuclides
- TAL Metals

Subsurface Soil:

- Target Analyte List Metals
- Uranium 233/234, 235, and 238
- Plutonium and Americium
- Nitrate

Groundwater (bedrock):

- None

Surface Water:

- None

Surface Soil:

- None

4.3 PROPOSED ACTIVITIES AND LOCATIONS

4.3.1 Ecological Field Sampling Plan

Sampling Strategy

The basic Ecological field sampling strategy will follow the approach that has evolved during the development of the environmental evaluation (EE) process for each individual operable unit (OU) at the Rocky Flats Plant (RFP). Both a Reference Area comparison and a Synoptic Sampling approach will be utilized. To facilitate this approach, sampling grids will be collocated (i.e., sampling sites where a full suite of samples will be taken for each endpoint) with biased sample sites. The immediate result of this design will be a stronger weight-of-evidence approach. This approach follows the outline recommended by the EPA document *Framework For Ecological Risk Assessment* (1988b). The objectives that are stated in the OU 11 Work Plan parallel the appropriate guidance which is consistent with the objectives of EEs occurring in other RFP OUs.

The field sampling design will produce data for the analyses, study and comparison of reference sites and individual sites at OU 11. Comparisons between spray and non-spray areas is necessary to isolate potential changes resulting from the impacts of adding increased moisture and nitrates to a moisture and nutrient-limited rangeland environment.

A matrixed sampling strategy for OU 11 field operations with the given field tasks (endpoints) matrixed is presented in Appendix E, Table E-1. In addition, the proposed field sampling methods to be utilized are presented for each endpoint in Table E-1 . Table E-2 in Appendix E summarizes the sampling design intensity for the study area.

Sampling Locations

The terrestrial sampling locations will include the selection of three types of sites (i.e., sprayed, non-sprayed, and reference) within the somewhat homogeneous mesic mixed grassland habitat type. Study areas, or areas considered potentially impacted by the past spray activities, will include two types of sites: sprayed and non-sprayed sites. Data gathered at the two types of study area sites will be compared with that gathered at the reference areas. Reference sites are those considered unimpacted by RFP activities and thus may be used as scientific controls.

Aquatic sampling will occur in the one perennial aquatic site, surface water pond #128, located downgradient of OU 11. This permanent pond collects the majority of the surface runoff from the study area.

Study Areas

A preliminary review of the abiotic media data has revealed that the level of contaminants within the study are considered very low. While areas that were not sprayed will be studied, it will be necessary to focus more on areas within the OU that are most likely to have the highest concentrations of contaminants; therefore, sampling areas will be selected in locations that received maximum spray and have surface channel flow. Here the sprayed water may have ponded, concentrating contaminants near the surface, and subsequently infiltrated the soil, potentially carrying contaminants into the rooting zone and further into shallow groundwater zones.

Two study sites will be selected within the OU, allowing a classical rangeland study design in combination with the current ecological risk assessment approach. Areas within the OU that were sprayed will be statistically compared to areas that were not sprayed in order to measure the potential positive or negative impacts of spraying the floral and faunal communities. Data from these sites may then be compared separately or they may be combined and then compared to data gathered in the reference areas as described in the OU 11 Work Plan.

Reference Area Selection

Selection of reference areas selection will be based upon the Ecology SOP,#5-21200-OPS-EE Volume V, Section 6.1.5. In general, reference sites will be chosen based on similarity of vegetation, habitat types, and physical attributes such as soil type, slope, aspect, and geographic proximity to the study area. Sites that received spray application were compared with topographically similar areas the did not receive spray or overspray; sites within OU 11 that did not receive direct spray application of wastewaters were compared to topographically similar areas in the same manner. However, the ecosystem is dynamic, and the physical attributes for reference site selection may not necessarily correspond to ecological differences. Therefore, the choice of reference sites will also be influenced by the objectives and endpoints of the study.

Aquatic Sampling

Because only one downgradient ditch and surface water pond #128 presently contain water, a contingency for sampling aquatics is proposed. During the fall season, the lack of surface water in the study area and vicinity limits the number and location of aquatic sampling sites. Although the sample statistics will be based on only one location downgradient of OU 11, several aquatic populations will be sampled and compared to the reference area, Lindsay Pond. This will provide adequate information for the appropriate statistical analyses. In the event a sufficient quantity of fish cannot be obtained for tissue analysis, emphasis will be placed on amphibians and their larvae. In addition, other biota distributed throughout the water column will be sampled to assist in the determination of bioaccumulation.

During the fall of 1993, a survey will be conducted to determine water chemistry and species composition in the permanent aquatic ecosystem contained within pond #128. Species presence will be determined by quantitative methods so that data can be statistically compared with that from Lindsay Pond.

Toxicity Testing

A determination regarding the necessity for terrestrial and aquatic sample collection is dependent upon the results of the Effects Assessment to be performed at the conclusion of the 1993 fall field sampling season. The decision to conduct tissue analyses is dependent upon the definition of a Target Analyte List (TAL), a narrow selection of the Contaminants of Concern

(COC) including metals, inorganics, nitrates, pesticides, and PCBs. The TAL analytes can only be determined after background levels are established. Not all of the potential COCs will be appropriate for analysis in biological tissue.

If toxicity tests are required, the collection of periphyton and selected aquatic macrophytes, amphibians and macro-benthos will be conducted for TAL analytes in the spring of 1994. In addition, sediments and macrophytes will be sampled for total nitrogen (N). All analysis will be consistent with General Radiochemistry and Routine Analytical Services Protocol (EG&G 1990) Data Quality Objectives (DQOs).

Terrestrial tissues will be collected and preserved from the fall 1993 field season. Grasshoppers (Arthropods) will be frozen and two forb species (i.e., Western ragweed, *Ambrosia psilostachya* DC; White sage, *Artemisia ludoviciana* Nutt,) and two Graminoid species (i.e., Big Bluestem, *Andropogon gerardii* Vitman; Canada Bluegrass, *Poa compressa* L.) will be collected and air dried until a determination of the necessity for toxicity testing is made. Fall collection of these biotic components is necessary because this is the time when their production is optimum. Therefore, their uptake of possible contaminants is greatest at that time.

It is expected that few analytes, if any, will be selected for toxicity testing, due to the nature of the contaminants and the historical use of the land. Toxicity testing will be conducted only if bioaccumulation is a factor; however, no food web analysis is anticipated at this time. Emphasis will be placed on total Nitrogen determinations and perhaps the metals listed in the work plan (i.e., mercury, lead, and arsenic) . Plutonium is not expected to be an issue because the highest isolated concentration at OU 11 is 0.59 pCi/gram. The standard for recreational areas is 100 pCi/gram and 3.5 pCi/gram for residential use. Mercury, lead, and arsenic are at concentrations that do not pose health or environmental threats elsewhere.

Format Changes

The OU 11 environmental evaluation will follow a three-phased approach based upon the EPA's *Framework For Ecological Risk Assessment* , and will consist of the following:

A. Problem Formulation,
B. Analysis - Characterization Of Exposure and Characterization of Ecological Effects, and
C. Risk Characterization if any adverse effects are observed

At the conclusion of each phase, a formal presentation will be given to the regulators along with a report for review and concurrence. The site-specific three-phased approach and analyses or activities associated with each step are presented below.

A. Problem Formulation

The Problem Formulation step consists of identifying the following: contaminants of ecological concern, identifying measurement and assessment endpoints, and identifying known ecological effects. This first phase consists of the following tasks to be carried out with data acquisition activities.

- Nature and Extent of Contamination:
  - Potential Stressor Characterization (rads, others)
  - Potential Aquatic Stressor Characterization (rads, chemicals, others)
- Potential Ecosystem at Risk (terrestrial, aquatic) :
  - Potential Ecological Effects
  - Ecosystem Components Measured
  - Effects Assessment
  - Selection of Assessment and Measurement Endpoints
- Conceptual Model:
  - Potential Stressors
  - Exposure Scenarios (terrestrial and aquatic pathways; terrestrial and aquatic indicator species

- Assessment Scenarios (i.e., assessment and measurement endpoints; related stressors)

At the conclusion of the above activities, a Status and Approach of the Analyses Phase will be initiated. This activity consists of the following:

- Toxicity Assessment of Chemical Concentrations in Abiotic and Biotic Media
- Direct Toxicity Assessment

B. Analysis of Exposure and Effects

The Analysis Phase consists of two parts: Exposure Characterization and Ecological Effects Characterization. Both phases involve field investigation activities.

1. EXPOSURE CHARACTERIZATION

- Stressor Characterization
- Ecosystem Characterization
- Exposure Analysis: fate and transport analysis; sources and exposure pathway of COCs; estimate exposure point concentrations by habitat, species, and exposure scenarios
- Exposure Profile: quantify the magnitude and spatial and temporal patterns of exposure

2. ECOLOGICAL EFFECTS CHARACTERIZATION

The assessment of the effects of contamination on biota will be determined by examining the literature regarding known effects of selected COCs, performing site-specific toxicity tests (laboratory and *in situ*), and reviewing the existing toxicity based criteria and standards.

The three essential steps that comprise the characterization of ecological effects are listed below.

- Evaluation of Relevant Effects Data
- Conducting the Ecological Response Analyses
- Completing a Stressor-Response Profile

C. Risk Characterization

In the final step of risk characterization, observed effects in potentially exposed habitats will be compared to reference areas and contaminant concentrations will be examined in relation to adverse effects. Observed effects are differences from OU 11 areas to reference areas, including percent of species, diversity differences, biomass productions, and amount of vegetative cover. Other analyses will include: bioaccumulation studies; toxicity test results in relation to observed adverse effects; comparison of estimated exposure point concentrations with criteria and standards; likely ecological risks associated with present and future land use scenarios; ecologically relevant ARARs; ecological considerations in selecting remedial alternatives; and uncertainty analysis. The two essential steps that comprise the risk characterization are listed below.

1. RISK ESTIMATION

- Integration of Stressor-Response and Exposure Profiles
- Uncertainty Analysis

2. RISK DESCRIPTION

- Risk Summary and Interpretation: Current and Future Adverse Effects, Ecological Significance

D. Ecological Risk Assessment for RFI/RI Report

4.3.2 Soil Sampling

Recent numerical analyses of the 1988 data indicate that the site is not statistically different from background except for concentrations of nitrate and plutonium. Soil samples collected in 1986 and 1988 were analyzed and showed that TAL metals and most inorganic compounds were near or below background. Nitrate was the only analyzed constituent that was well above background in certain locations; however, those analyses were performed several years ago and samples will be analyzed again under the Ecological Monitoring Program in 1993. Furthermore, nitrate is highly mobile in the environment through vegetation uptake, solubility in the pore water, and natural degradation into compounds such as ammonium, nitrite, and nitrogen gas. The nitrate content in soils tested in 1988 ranged from below detection levels to 150 mg/kg and it is very unlikely that concentrations currently remain that elevated. The proposed bore hole samples will also be analyzed for nitrate to assess the current status of contamination, which is anticipated to be well below the 1988 concentrations.

The original FSP identified the need for an extensive soil sampling program, requiring the collection of 75 samples for analysis of nitrate, TAL metals, and inorganic compounds. After close review and re-evaluation of existing data, the need for this number of samples cannot be justified. The surface radiation survey recently performed to identify the distribution of plutonium in surficial soils demonstrated that plutonium-239 and americium-241 occur at OU 11 at levels that are below detection limits (detailed in Table 2-1). The planned Ecological Evaluation will quantify the nitrate distribution in surficial soils and the impact of potential contamination on surface water. Subsurface soils will be sampled via core samples from the proposed bore holes and will be analyzed for nitrate, plutonium, and metals suites.

4.3.3 Monitoring Wells

4.3.3.1 Well Locations and Justification

Current Monitoring Network

The network of groundwater wells screened in the uppermost hydrostratigraphic unit (Rocky Flats Alluvium) at OU 11 is extensive for the purpose of monitoring the saturated zone. This network includes two upgradient wells, five wells within the IHSS boundary, six wells on the downgradient IHSS boundary, and an additional eight wells downgradient or to the sides of the IHSS. In addition, there are several wells completed in the underlying bedrock. This is an appropriate monitoring design in consideration of the non-point source dissemination of potential contaminants into the environment. No additional monitoring wells are proposed in the West Spray Field to monitor potential contamination in the saturated zone. Presently the primary hydrogeologic concerns are possible contaminated perched groundwater mounds in the West Spray Field unsaturated zone (Section 2.0 of this TM).

Perched Groundwater Conditions

Data supporting the existence of perched groundwater include historical water level data, water chemistry data, and information gathered during recent drilling operations. If WSF groundwater has been contaminated to significant levels above background because of spray application, perched groundwater has the potential of having the highest levels of contamination.

The screened intervals of the wells in the current monitoring system are either too deep to monitor perched conditions, or are screened through the entire thickness of the Rocky Flats Alluvium. Three wells with extensive screened intervals are 4986, 5186, and B410789. Nitrate/nitrite has been detected in all three wells at concentrations ranging from approximately 3 to 8 mg/l during the past several years. Concentrations were reported for nitrate/nitrite; however in this oxidizing environment, probably most of the nitrogen is present as nitrate. These concentrations do not constitute a concern in terms of risk-based nitrate groundwater quality standards, however they likely represent a dilution of shallow groundwater contamination with deeper groundwater from the saturated zone.

Four wells (1081,582, 682, and 782) were drilled in the West Spray Field area to depths of approximately 25 feet for the purpose of monitoring shallow groundwater conditions. Because well construction details for these wells were not available, all four wells were recently abandoned through WARP (Well Abandonment and Replacement Program). Recent water level measurements taken at these locations indicate that shallow groundwater exists at depths of between 20 and 25 feet. The highest nitrate/nitrite concentration documented from these wells was 143 mg/l from well 582. This measurement was

recorded in 1986, shortly after spray application ceased. Recent levels range from .3 to 2.5 mg/l.

Additional evidence of perched groundwater conditions was obtained when replacement wells 46192 and 46292 were drilled to bedrock. These wells were drilled with hammer technology using air as a drilling fluid. Sample returns indicated that water was encountered at a depth of approximately 25 feet.

Locations of Monitoring Wells

For the purpose of monitoring shallow groundwater conditions in the areas where maximum contamination is anticipated, six wells will be installed in the West Spray Field (Figure 4-2). The main criteria for the selection of well locations was that all wells be located within the irrigation sub-basins, or areas which received direct spray application. Secondary criteria included proximity to wells where contamination has been documented, position relative to surface runoff pattern, and position relative to the seismic data.

Seismic data were evaluated as a tool for locating wells; however it was concluded that the West spray Field seismic line had not been adequately calibrated to the subsurface geology. In addition, seismic processing was intended to enhance deeper portions of the geologic section rather than the uppermost 30 feet, where perched mounds are anticipated. For the purpose of validating the seismic data for future use, two bore holes will be located on the seismic line. Listed below are the six well locations and their justifications:

WSF-1 Located in Spray Area 1 between wells where elevated nitrate contamination and wells where perched conditions have been encountered. Located on surface runoff drainage resulting from spray application.

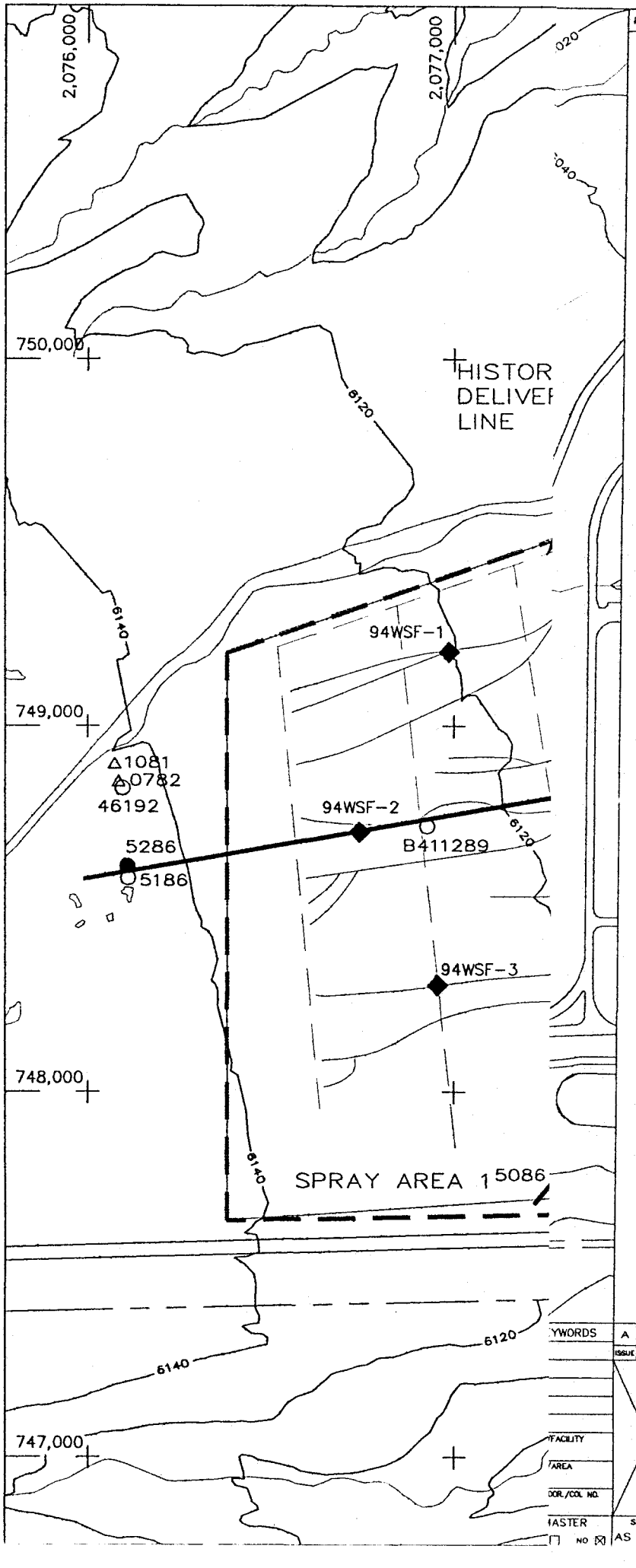
WSF-2 Located in Spray Area 1 near well 5186, where elevated nitrate/nitrite concentrations have been encountered. Located on seismic line.

WSF-3 Centrally located in the southern portion of Spray Area 1 on a surface runoff drainage resulting from spray application.

WSF-4 Centrally located in Spray Area 2 near well 0582 where the highest historical record of nitrate/nitrite in West Spray Field groundwater was recorded.

WSF-5 Located in Spray Area 2 on the seismic line.

WSF-6 Centrally located in Spray Area 3, where there is a lack of data.



PART	QUAN.	DESCRIPTION	MATERIAL

94WSF-1 ◆ PROPOSED GROUNDWATER MONITORING WELL LOCATIONS

B110989 ○ ALLUVIAL MONITORING WELL

4686 ● BEDROCK MONITORING WELL

0582 △ PRE-1986 MONITORING WELL

RCRA WASTE MANAGEMENT AREA

SPRAY AREAS

DRAINAGE FLOW LINE

6040 GROUND CONTOUR

PIPING (HISTORICAL)

SECTION CUT

N

SCALE 1" = 400'

400 200 0 800

300 100 400

CONTOUR INTERVAL = 20'

YWORDS	A	ORIGINAL ISSUE	10/05/93	MWB KAS MFK			
	ISSUE	DESCRIPTION	DATE	RFP	DOE	CLASS	JOB NO

DESIGNED BELL
DRAWN SCHACKLIN
CHECKED KRAESKI
APPROVED

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS AREA OFFICE GOLDEN, COLORADO

Rocky Flats Plant
GOLDEN, COLORADO 80401

OPERABLE UNIT 11 – WEST SPRAY FIELD

Locations of Proposed Monitoring Wells

SUBMITTED
APPROVED
RFP
APPROVED

SCALE: AS NOTED

SIZE	DRAWING NUMBER	ISSUE	SHEET
B	FIGURE 4-2	A	OF

FACILITY
AREA
DOR./COL NO.
MASTER NO

4.3.3.2 Monitoring Well Installation Program

Six groundwater monitoring wells will be installed as described in Section 4.3.3.1 above, for the purpose of characterizing subsurface lithologies and perched water conditions. After completion and development, these wells will be sampled quarterly for a period of one year, at which time results will be evaluated for further sampling needs. Results from drilling, bore hole sampling, and groundwater monitoring will be used to assess the need for further characterization of OU 11.

Activities related to the Monitoring Well installation Program will be carried out in accordance with all applicable EMD OPs. The following EMD OPs are applicable in this program.

FO.01	Monitoring and Dust Control
FO.02	Transmittal of Field QA Records
FO.03	General Equipment Decontamination
FO.04	Heavy Equipment Decontamination
FO.05	Handling of Purge and Development Water
FO.06	Handling of Personal Protective Equipment
FO.07	Handling of Decontamination Water and Wash Water
FO.08	Handling of Drilling Fluids and Cuttings
FO.09	Handling of Residual Samples
FO.10	Receiving, Labeling, and Handling Environmental Materials Containers
FO.11	Field Communications
FO.12	Decontamination of Facility Operations
FO.13	Containerization, Preserving, Handling, and Shipping of Soil and Water Samples
FO.14	Field Data Management
FO.15	Photoionization Detectors (PID) and Flame Ionization Detectors (FID)
FO.16	Field Radiological Measurements
FO.18	Environmental Sample Radioactivity Content Screening
FO.23	Management of Soil and Sediment Investigative Derived Materials (IDM)
GW.01	Water Level Measurements in Wells and Piezometers
GW.02	Well Development
GW.05	Field Measurement of Groundwater
GW.06	Groundwater Sampling

GT.01	Logging Alluvial and Bedrock Material
GT.02	Drilling and Sampling Using Hollow-Stem Auger Techniques
GT.04	Rotary Drilling and Rock Coring
GT.05	Plugging and Abandonment of Bore holes
GT.06	Monitoring Well and Piezometer Installation
GT.10	Bore hole Clearing
GT.17	Land Surveying
GT.24	Approval Process for Construction Activities on or near IHSSs

Justification of Preferred Drilling Technology

Sonic Drilling and split spoon sampling are the preferred drilling and sampling technology to be used; the advantages of utilizing sonic drilling are summarized below. A Document Change Notice (DCN) pertaining to sonic drilling will be written for EMD OP GT.04, Rotary Drilling and Rock Coring.

Achieving good sample recovery for lithologic and chemical characterization is the main objective to be accomplished by using sonic drilling. As mentioned in Section 2.1, most of the wells previously drilled on OU 11, were drilled with hammer technology. Lithologic logs of these wells lack accuracy and detail. Hollow-stem auguring, the standard method of drilling bore holes at RFP, can provide undisturbed samples for analyses, and this technique may be adequate; however there is a risk of obtaining poor sample recovery in the unconsolidated sands and gravels of the West Spray Field. Because the perched zones of interest are relatively thin, good sample recovery is critical to characterization efforts.

Sonic drilling technology has a distinct advantage for use at RFP over conventional auger and percussion drilling because it allows continuous sample retrieval through cobbles and boulders. By utilizing a relatively high-frequency oscillating drill head combined with downward pressure and low rotation, the drill string is advanced through unconsolidated and consolidated materials. Additional advantages of sonic drilling are: its rapid rate of penetration; the generation of small drilling waste volume at the drill site and; the speed and ease of development of monitoring wells (critical in perched zones where little water may be available for well development).

Sonic drilling has a limited track record in the environmental industry. Approximately two years ago, sonic drilling was used for a site assessment of the RFP Wind Site. The program was experimental and involved modifications to standard sonic drilling equipment. Problems relating to sample recovery were encountered, including plugging of the drill bit and recoveries of greater than 100 percent (probably due

to expansion of sample and extension of the sample in the core barrel which has a smaller diameter than that of the drilling bit). Sonic drilling technology has improved since it was employed at RFP, and reports of is success at other sites, such as Hanford, have been received. However, due to the limited use of sonic drilling in the environmental industry, the first well at the West Spray Field will be a test case. Providing drilling objectives are successfully met, the remaining five wells will be drilled in a similar manner. In the event that sonic drilling is not successful in a test case scenario, hollow stem augering will be used as a backup alternative.

Drilling Procedures and Bore Hole Sampling

Sonic Drilling will be employed, and core samples will be collected in a split spoon sampler. Visual logging of the alluvial materials will be performed according to Operating Procedure (OP) GT.01, Logging of Alluvial and Bedrock Material. All sampling equipment will be protected from the ground surface with clear plastic sheeting. Sampling procedures are defined in OP GT.02, Drilling and Sampling Using Hollow-Stem Auger Techniques. In addition, samples for water content measurements will be collected every two feet. Water content measurements will be determined in the field and also in a geotechnical laboratory. Water content data for each boring will be collected in the field using a "Speedy Soil Moisture Tester", manufactured by Soiltest Incorporated and will be used to design each monitoring well. Samples released to the geotechnical laboratory will be stored after analysis for the possibility of future use. (In the event that future vadose zone characterization is deemed necessary, these samples might be used to construct moisture characteristic curves). Drilling and sampling activities will be conducted in accordance with the Site-Specific Health and Safety Plan.

All drilling equipment, including the rig, water tanks, drill rods, samplers, etc., will be decontaminated before arrival at the work site. The drill rig will be decontaminated between each monitoring well installation, and sampling equipment will be decontaminated between samples. Equipment will be inspected for evidence of fuel oil or hydraulic system leaks. OP FO.03, General Equipment Decontamination and OP FO.04, Heavy Equipment Decontamination will be adhered to. If lubricants are required for down-hole equipment, only pure vegetable oil will be used.

Prior to drilling, approval for construction activities will have been obtained in accordance with OP GT.24, and drill sites will have been cleared in accordance with GT.10. Well locations will have been numbered and identified with stakes. During site preparation, an exclusion zone will be established according to the Site-Specific Health and Safety Plan, and the drill rig will be set up. The total depth of each well will be determined by the EG&G project manager. Holes will be drilled to penetrate a perched saturated zone (if encountered) and underlying aquitard and a monitoring well will be installed in accordance with the

monitoring well section of this TM. If a perched water table is not encountered, the boring will be advanced to the saturated zone. At that time the EG&G project manager will determine if the bore hole should be abandoned in accordance with GT.05 or drilled to the alluvial/bedrock contact. Since OU 11 subsurface lithologic data is incomplete, borings may be advanced to penetrate the entire Rocky Flats Alluvium for the purpose of supporting the OU 11 data acquisition plan. After a boring has been advanced to penetrate bedrock, it will be abandoned in accordance with GT.05. Borings will be sampled in accordance with OP GT.02, Drilling and Sampling Using Hollow-Stem Auger Techniques, and lithologically logged in accordance with OP GT.01, Logging Alluvial and Bedrock Material. During drilling operations, the cuttings will be containerized according to OP FO.08, Handling Drilling Fluid and Cuttings.

For all borings, soil samples will be collected from ground surface to the saturated zone. Two-foot composite samples for chemical analyses will be collected from ground surface to a depth of 30 feet. Based on existing data it is anticipated that perched mounds with the potential for significant contamination may exist at depths less than 30 feet. From a depth of 30 feet to the saturated zone, six-foot composite samples will be collected. Samples will be analyzed for the contaminants of concern as defined in Section 4.2. In order to collect these composite samples, the recovered material will be placed in a safe location, out of direct sunlight, until the appropriate number of core samples have been collected. The recovered material will be classified, logged, peeled disaggregated, mixed into a composite, and placed in appropriate containers for laboratory analysis according to OP FO.13, Containerizing, Preserving, Handling, and Shipping of Soil and Water Samples. Procedures for sample peeling, handling and compositing will be followed according to OP GT.02, Drilling and Sampling Using Hollow Stem Auger Techniques.

Subsequent to sample collection the exterior of the sample containers will be decontaminated according to FO.03, General Equipment Decontamination, and placed in coolers lined with a plastic bag designated for sample transportation. Blue ice or equivalent will be placed in each cooler. Official custody of samples will be maintained and documented from the time of collection until the time that valid analytical results have been obtained or the laboratory has been released to dispose of the sample. Chain-of-Custody procedures will be in accordance with OP FO.13, Containerizing, Preserving, Handling, and Shipping of Soil and Water Samples.

Monitoring Well Installation Procedures

As specified in the IAG, groundwater monitoring wells will be installed according to OP GT.06, Monitoring Well Installation is outlined below.

The screen intervals of all wells will be sufficient to monitor perched groundwater conditions. The well design specifics for each well will be determined after the bore hole has been drilled and the water content measurements and lithologic data have been analyzed. It is anticipated that the well will be two inches in diameter upon completion. However, since new drilling technologies are anticipated, then casing size will be evaluated so that the ratio of filter pack to well diameter is appropriate. The objective is to maintain an approximate two inch filter pack around the well bore annulus. Well casings will consist of new, threaded flush-joint schedule 40 poly-vinyl chloride (PVC). The well casing will extend from the top of the well screen to approximately two feet above ground surface. The tops of all well casings well be fitted with slip-on or threaded PVC caps. All joints within the casing string will be threaded. O-rings or Polytetrafluoroethylene (PTFE) tape will be wrapped around the joint threads to improve the seal. All well casings will be steam cleaned and stored in plastic sleeves prior to use.

Well screens will consist of new threaded PVC pipe with 0.010-inch factory-machined slots or wrapped screen. All well screens will have an ID. equal to or greater than that of the well casing. The wall thickness will be the same as the well casing. A two-foot deep sediment sump will be used beneath the screen. A threaded or slip-on cap secured with stainless steel screws will be provided at the bottom of the sump.

The filter pack material will be chemically inert, rounded, silica sand of approximately 16-40 gradation. The filter pack will extend approximately two feet above the top of the screen unless otherwise specified.

Bentonite seals will be installed above and below the filter pack. The bottom seal will be designed such that the perched mound and underlying aquitard are sealed from the lower portion of the hydrostratigraphic unit. A seal will consist of a layer of bentonite pellets that is at least three feet thick when measured immediately after placement, without allowance for swelling. The annular space between the well casing and the bore hole will be grouted from the top of the bentonite seal to ground surface.

Monitoring Well Development and Sampling Procedures

Monitoring wells will be developed for groundwater sampling as specified in OP GW.02, Well Development. Monitoring well development is the process by which the well drilling fluids and mobile particulates are removed from within and adjacent to newly installed wells. The objective of well development activities is to provide groundwater inflow that is as physically and chemically representative as possible of the hydrostratigraphic unit or aquifer.

Well development will be conducted as soon as practical after installation, but no sooner than 48 hours after grouting and pad installation is completed. Monitoring wells will be developed utilizing low energy

methods. An inertial pump or bottom discharge/filling bailer will be used in development activities.

All newly installed wells will be checked for the presence of immiscible layers prior to well development. Once determined free of an immiscible layer, a water level measurement will be taken according to OP GW.01, Water Level Measurements in Wells and Piezometer, and well development activities will proceed. The water level measurement along with the total depth measurement and the diameter will be used to determine the volume of water in the well casing.

Formation water and fines will be evacuated by slowly lowering and raising the inertial pump or bailer intake throughout the water column. Development equipment will be protected from the ground surface with clear plastic sheeting. Development equipment, including bailers and pumps, will be decontaminated before well development begins and between well site activities according to OP FO.03, General Equipment Decontamination.

Estimated recharge rates will be measured following the procedures outlined in OP GW.01, Water Level Measurements in Well and Piezometers.

Groundwater sample collection will be performed in accordance with OP GW.06, Groundwater Sampling. The groundwater will be sampled and analyzed for analytes included in the Contaminants of Concern Section (Section 4.2) of this technical memorandum provided sufficient groundwater is collected.

The following field measurements will be obtained at the time of sample collection:

pH
specific conductance
temperature
dissolved oxygen
barometric pressure

The groundwater samples will be analyzed for the analytes mentioned in the Contaminants of Concern Section of this TM (Section 4.2) provided enough groundwater is available. If there is not enough groundwater to sample for all analytes, the analytical priority stated in the COC section will be followed. Samples will be handled according to OP FO.13, Containerizing, Preserving, Handling, and Shipping of Soil and Water Samples, and FO-03, General Equipment Decontamination.

This Field Sampling Plan addresses the procedures for conducting the proposed field activities as well as the proposed analytical suites for the samples collected during the field investigation. A Quality Assurance Project Plan (QAPjP) is an element of the FSP that identifies QA objectives for data collection, analytical procedures, calibration, and data reduction, validation and reporting. The QAPjP, in conjunction with Standard Operating Procedures (SOPs), has been prepared by EG&G and submitted to the EPA and the CDH for review and comment. All field and analytical procedures will be performed in accordance with the methods described in the QAPjP and SOPs unless otherwise specified in this FSP.

5.1 Internal QC Control Samples

The objective of the QAPjP is to provide a framework to ensure that all sampling and analytical data achieve specific data quality standards. These standards ensure that PARCC parameters for the data are known and documented. All samples sent for CLP Level IV analyses will be handled in accordance with CLP guidelines. QC procedures for non-CLP methods will be developed as needed using standard methods.

QC samples will be collected in conjunction with the investigative samples to provide information on data quality. Equipment rinsate blanks, trip blanks, field duplicates, laboratory blanks, laboratory replicates, and laboratory matrix spike and matrix-spike duplicates are the commonly collected samples. Trip blanks generally pertain only to volatile organic analyses; whereas other QC samples may pertain to all of the analytical parameters specified for investigative samples in the FSP.

Rinsate blanks will be collected by pouring distilled/deionized water through decontaminated sample-collection equipment and submitted for the same analyses as the investigative samples. Rinsate blanks monitor the effectiveness of decontamination procedures.

Field duplicates will be collected and analyzed to provide information regarding the natural

variability of the sampled media as well as evaluate analytical precision. Table 5-1 presents the suggested field QA/QC sample collection frequency.

Table 5-1
Field QA/QC Sample Collection Frequency

Activity	Frequency
Field Duplicate[1]	1 in 10
Field Preservation Blanks	1 sample per shipping container (or a minimum of 1 per 20 samples)
Equipment Rinsate Blank	1 in 20 or 1 per day [2]
Triplicate Samples (benthic samples) [3]	For each sampling site.

1. For samples to be analyzed for inorganics.
2. One equipment rinsate blank in twenty samples or one per day, whichever is more frequent, for each specific sample matrix being collected when non-dedicated equipment is being used.
3. For samples collected for tissue analysis.

Analytical procedures and conditions are tested using laboratory blanks and replicates. Laboratory matrix spikes and matrix-spike duplicates measure analytical accuracy by providing data on matrix effects/interferences and components interfering with instrument responses. The frequency of collection and analysis of laboratory QC samples is dictated by the prescribed analytical method as cited in the General Radiochemistry and Routine Analytical Services Protocol (GRRASP) (EG&G 1990).

5.2 Accuracy

Accuracy is a quantitative measure of data quality that refers to the degree of difference between measured or calculated values and the true value. One of the measures of analytical accuracy is expressed as percent recovery of a spike of a known concentration that has been added to an environmental sample before analysis (EG&G 1992c). The control limits that have been

established to achieve accuracy objectives for Level IV data quality are outlined in Table B-1 of Appendix B in the QAPjP (EG&G 1992c). Accuracy limits for inorganic analytes are listed in that table. Samples requiring 24-hour turnaround (i.e., indicator parameter analyses) have accuracy objectives consistent with Level III data quality. The analyses for indicator parameters are non-CLP. Non-CLP analyses will be conducted according to SW-846 (3rd Ed.) and EPA Methods for Chemical Analyses of Water and Wastes. The accuracy criteria for these samples are specified in the respective methods.

5.3 Precision

Precision is a quantitative measure of data quality that refers to the reproducibility or degree of agreement among replicate measurements of a single analyte. Analytical precision for a single analyte may be expressed as a percentage of the difference between results of duplicate samples and matrix spike duplicates for a given analyte (EG&G 1992c). The control limits that have been established to achieve precision objectives for Level IV data quality are outlined in Table B-1 of Appendix B in the QAPjP (EG&G 1992c). Precision limits for inorganic analytes are outlined in that table. The analyses for indicator parameters are non-CLP. Non-CLP analyses will be conducted according to SW-846 (3rd Ed.) and EPA Methods for Chemical Analyses of Water and Wastes. The precision criteria for these samples are specified in the respective methods.

5.4 Sensitivity

Sensitivity defines the lowest concentration (detection limit) a method can accurately and repeatedly detect for particular chemical or compound. The required detection limits for CLP analyses are outlined in Table B-1 of Appendix B in the QAPjP (EG&G 1992c). Detection limits for non-CLP indicator parameter analyses shall be those specified in the respective EPA methods.

5.5 Representativeness

Representativeness is a qualitative measure of data quality defined by the degree to which the data accurately and precisely represent a characteristic of a population, parameter variations

at a sampling point, a process condition, or an environmental condition (EG&G 1992c). Representativeness is ensured through the careful development and review of the sampling strategy outlined in the FSP and SOPs for sample collection, analysis and field data collection.

5.6 Data Comparability

Comparability is a qualitative measure defined by the confidence with which one data set can be compared to another. Differences in field and laboratory procedures greatly affect comparability. Comparability is ensured by implementation of the FSP, standardized analytical protocols, SOPs for field investigations, and by reporting data in uniform units.

5.7 Completeness

Completeness is a quantitative measure of data quality expressed as the percentage of valid or acceptable data obtained from a measurement system (EG&G 1992c). The target completeness objective for both field and analytical data for this project is 90 percent.

5.8 Sample Management

Good sample management is a critical component of the OU 11 Revised FSP. It ensures that sample integrity is maintained from sampling through analysis. Sample management, including labelling, sampling, decontamination, preservation/storage, chain of custody and shipping will be conducted in accordance with applicable SOPs, unless otherwise modified as necessary. Table 5-2 lists the types of containers, preservation and holding times for samples and/or sample suites for each media.

5.9 Data Reporting

Field data will be collected and reported as outlined in SOP FO.14, Field Data Management. Laboratory data from the 24-hour turnaround samples will be reported in a facsimile transmittal to the on-site manager and EG&G personnel or their designees, in order to facilitate decision making for the observational sampling approach. An electronic transmittal, in RFEDS format, will subsequently be sent to EG&G or their designees for input into the OU 11 database.

The EPA-CLP sample results will be reported as specified in the GRRASP and the EG&G "Specifications for Providing the Electronic Deliverable Lab Data to the Rocky Flats Environmental Data Management System (EG&G 1991a)."

TABLE 5-2
SAMPLE CONTAINERS, SAMPLE PRESERVATION, AND SAMPLE HOLDING TIMES
FOR OU 11 CONTAMINANTS OF CONCERN

MATRIX	PARAMETER	CONTAINER	PRESERVATIVE	HOLDING TIME
SOIL	TAL Metals	1X8 oz. wide-mouth glass jar	none	6 months (28 days for mercury)
	Nitrates	8 oz. wide mouth glass with Teflon®-lined closure	none	As Soon As Possible
	Radionuclides	500 mL wide-mouth glass jar	none	none
WATER	Aluminum	1 X 1 L polyethylene bottle	nitric acid pH<2	6 months
	Manganese	1 X 1 L polyethylene bottle	nitric acid pH<2	6 months
	Nitrates	2 L/P, glass	1:1 Sulfuric Acid, pH<2, Cool, 4 degrees C	28 days
	Radionuclides	3 X 4 L plastic containers (for full suite)	HNO3	6 months
	TAL Metals	1 X 1 L polyethylene bottle	nitric acid pH<2	6 months

6.0
SCHEDULE

A schedule for implementation of the OU 11 revised field sampling plan and development of a risk assessment and RFI/RI Report will be provided upon approval of this Technical Memorandum by the Colorado Department of Health and the Environmental Protection Agency. This schedule will be agreed upon by all Interagency Agreement signers.

Brock, R. R. 1976. "Hydrodynamics of Perched Mounds" *Journal of the Hydraulic Division of The American Society of Civil Engineers.* August.

Colorado Water Quality Control Commission. 1992. *Segment 5 Standards.* December.

Crump, K. S. 1993. *Evaluations of Recommendation by Gilbert for Comparing Environmental Restoration Site Results to Background Concentrations.* ICF Kaiser Engineers. Submitted to D. M. Smith, EG&G Rocky Flats, Inc. September.

EG&G Energy Measurements. 1989. *An Aerial Radiological Survey of the United States Department of Energy's Rocky Flats Plant and Surrounding Area.* Golden, Colorado. July.

EG&G Rocky Flats, Inc. 1990. *General Radiochemistry and Routine Analytical Services Protocol (GRRASP).* ER Program, Rocky Flats Plant, Golden, Colorado. August.

EG&G, Rocky Flats, Inc. 1991a. *Specifications for Providing the Electronic Deliverable Lab Data to the Rocky Flats Environmental Data Management System.* ER Program, Rocky Flats Plant, Golden, Colorado. October.

EG&G, Rocky Flats, Inc. 1991b. *Final Phase I RFI/RI Work Plan, Rocky Flats Plant, Present Landfill IHSS 114 and Inactive Hazardous Waste Storage Area IHSS 203 (Operable Unit No. 7).* ER Program, Rocky Flats Plant, Golden, Colorado. December.

EG&G, Rocky Flats, Inc. 1992a. *Final Work Plan Phase I RFI/RI Work Plan for OU 11.* ER Program, Rocky Flats Plan, Golden, Colorado. March.

EG&G Rocky Flats, Inc. 1992b. *Final Background Geochemical Characterization Report for 1992, Rocky Flats Plant.* Golden, Colorado. September.

EG&G, Rocky Flats, Inc. 1992c. *Quality Assurance Project Plan for CERCLA Remedial Investigations and Feasibility Studies and RCRA Facility Investigations and Corrective Measures Studies Activities.* ER Program, Rocky Flats Plant, Golden, Colorado. June.

EG&G, Rocky Flats, Inc. 1993a. *Proposed Statistical Sampling Plan for Surface Soils in Operable Unit 11.* Golden, Colorado. August.

EG&G, Rocky Flats, Inc. 1993b. *Preliminary Analysis of Treatment and Disposal Options for Solar Ponds Wastes.* Environmental Restoration Management. Rocky Flats Plant, Golden, Colorado. February.

Hem, John D. 1992 (fourth ed.) *Study and Interpretation of the Chemical Characteristics of Natural Water.* U. S. Geological Survey Water-Supply Paper 2254. Washington. 263 pp.

Lauer, W. 1993. Discussion with Bill Lauer of the Denver Water Department.September.

Manning, G. *Assessment of Contaminant Soil and Groundwater Concentration Preliminary Remediation Goals for Rocky Flats Operable Unit 11.*

National Priminary Drinking Water Regulation, and 40 CFR 143, National Secondary Drinking Water Regulation. 1992. Revised July.

Rockwell International, Inc. 1987. *Annual Groundwater Monitoring Report for RCRA Regulated Units.* Rocky Flats Plant, Golden, Colorado. March (et seq.).

Rockwell International. 1988a. *West Spray Field Closure Plan.* Appendix I-6 of the Rocky Flats Plant Post Closure Core Permit Application. Rocky Flats Plant, Golden, Colorado. November.

Rockwell International. 1988b. *General Laboratory West Spray Field Soil Sample Report.* Report No. 0024115, Enclosure to letter WSF-1 dated July 18, 1988.

U.S. Department of Energy. 1991. *Phase I RFI/RI Work Plan for OU 11.* Environmental Restoration Program. U.S. Department of Energy. December.

U.S. Department of Energy. 1992. *Phase I RFI/RI Work Plan for the Solar Evaporation Ponds (OU 4).* Rocky Flats Plant, Golden, Colorado. January.

U.S. Department of Energy. 1993. *Identification of Operable Unit No. 3 Area of Concern Draft Report.* Rocky Flats Plant Environmental Restoration Program, Golden, Colorado. July.

U.S. Environmental Protection Agency. 1987. *Data Quality Objectives for Remedial Response Activities.* Washington. U.S. Environmental Protection Agency. EPA/543/G-87/003, OSWER Directive 9355.0-7B. March.

U.S. Environmental Protection Agency. 1988a. *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA Interim Final.* Washington. U.S. Environmental Protection Agency. EPA/540/8890/004, OSWER Directive 9355.3.01. October.

U.S. Environmental Protection Agency. 1988b. *Framework for Ecological Risk Assessment.* Washington. U.S. Environmental Protection Agency. EPA/630/R-92/001. February

U. S. Environmental Protection Agency. 1989. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part A), Interim Final.* EPA/540/1-89/002. December.

U. S. Environmental Protection Agency. 1992. *Guidance for Data Useability in Risk Assessment (Part B).* Publication 9285.7-09B. May.

APPENDIX A

ISOTOPE RATIO METHOD FOR DETERMINING URANIUM CONTAMINATION AT OU 11

Appendix A
Isotope Ratio Method for Determining Uranium Contamination at OU 11

The presence of high concentrations of uranium isotopes in OU 11 subsurface soils can be attributed to either West Spray Field (WSF) activities or naturally occurring uranium. A mathematical method has been employed to evaluate the isotope ratios that demonstrates conclusively that uranium in OU 11 subsurface soils is natural uranium that has not been contaminated with either enriched or depleted uranium resulting from Rocky Flats Plant (RFP) releases. This appendix describes the method used to determine this intriguing fact.

* * * * * * * * * * * * *

Uranium occurs naturally and has been extensively mined from the Coal Creek Canyon area, upgradient of the RFP. The 1974 Masters Thesis entitled "Exploration for Buried Channels by Shallow Seismic Refraction and Resistivity and Determination of Elastic Properties at Rocky Flats, Jefferson County, Colorado" by Ruy Bruno Bacelar de Oliveira, addressed the issue of the depositional environment and the proximity of the OU 11 area to Coal Creek Canyon. The objectives of the study included describing the significance of buried channels at the contact between the alluvium and bedrock. It was concluded that these channels deposits, with the provenance in Coal Creek Canyon, may have important accumulations of minerals like uranium and gold. Therefore, it would not be unusual to have naturally high concentrations of natural uranium at OU 11.

Weapons production at the RFP over the past 40 years has made use of plutonium, highly enriched uranium, and depleted uranium. If even small amounts of either enriched or depleted uranium have been released to the RFP environment through RFP processes, then the natural isotope ratios will have been altered. The natural isotope ratios for uranium are:

- U^{238} = 0.99283
- U^{235} = 0.00711
- U^{234} = 0.000054
- U^{236} = 0.000006

The enriched uranium used at the RFP in weapons production typically has the following isotopic ratios:

- U^{238} = 0.0532
- U^{235} = 0.9324
- U^{234} = 0.0101
- U^{236} = 0.0043

Generally, uranium isotope activities are reported in picoCuries. In order to determine the isotope ratio of U^{234} to U^{238} in a given sample, the number of atoms of each isotope in the sample must be computed. The number of atoms is related to the activity by the equation:

The number of atoms of each isotope is given by:

The halflife constants ($T1/2$) for the uranium isotopes are:

- $U^{238} = 4.51 \times 10^{9}$ years
- $U^{235} = 7.1 \times 10^{8}$ years
- $U^{234} = 2.47 \times 10^{5}$ years
- $U^{236} = 2.39 \times 10^{7}$ years

The corresponding decay constants ( ) are:

- $U^{238} = 1.54 \times 10^{-10}$ years^{-1}
- $U^{235} = 9.76 \times 10^{-10}$ years^{-1}
- $U^{234} = 2.806 \times 10^{-6}$ years^{-1}

N, the number of atoms, is calculated by dividing the activity of each uranium isotope in a single sample, as determined through laboratory analysis, by the decay constant for the corresponding isotope. A ratio of Ns for different isotopes is calculated and compared to the same ratio as natural uranium. The naturally occurring ratio of U^{234} to U^{238} is 5.43×10^{-5}. The enrichment process yields a U^{234} to U^{238} ratio of 0.19; four orders of magnitude greater than natural uranium.

Using this procedure and activity data collected in the 1986 and 1988 soil sampling programs at the WSF, ratios of $U^{233,234}$ to U^{238} were computed. $U^{233,234}$ was used because it was provided from the laboratory analyses. U^{233} is a very small component of uranium because it is not a naturally occurring isotope. Its use at Rocky Flats had been very limited and it is not expected to be present in enriched, depleted, or naturally occurring sources of uranium. The tabulated data (Table 1) and graph (Figure 1) of these ratios are attached. Each bar in the graph represents the ratio of $U^{233,234}$ to U^{238} for each sample. The center horizontal line illustrates the natural ratio of 5.34×10^{-5}. The upper and lower horizontal lines represent the error inherent in the analytical procedure due to lack of precision. This error range was obtained from the scatter in the data attained from samples collected from the buffer zone in 1986.

Calculations of the amount of contamination resulting from the enrichment process were computed. A one percent enrichment contamination, i.e., one percent of the uranium present is *enriched uranium, would result in a* $U^{233,234}$ to U^{238} ratio of 1.56×10^{-4}. This line is shown on the graph to indicate how even a very small amount of enriched uranium contamination is dramatically demonstrated by this presentation method.

A statistical analysis was performed on these data to numerically identify whether the data collected from OU 11 are different than the background data collected in 1986. The analysis involved a comparison of median values as opposed to means because medians are not affected by

outliers. The probability of having outliers is greater in data collected from the WSF than background because of the number of sample observations (45 and 9, respectively). A notched box plot was produced to graphically show that the medians are not significantly different (Figure 2). The notched box plot was used to summarize the center and spread of the two data sets. Box plots are typically used to compare data that are random in time and space. This is not the case for the data used; however, because both data sets are not random in time or space, the use of a box plot is valid for a side-by-side comparison. The notches of the two boxes (URATIO for the background data and RWSF for WSF data) overlap which means that the medians of the data sets are the same with a 95 percent level of significance. A 95 percent level of significance is used loosely because the data are not random. Furthermore, both notches overlap the theoretical natural ratio of 5.43×10^{-5}, which suggests that the median values for the buffer zone and the WSF are not significantly different than the natural ratio.

Uranium isotope ratios from the solar pond area soil samples were compared for two reasons. First, it is known that the solar ponds received uranium-contaminated liquids (enriched and depleted). It is speculated that an unnatural isotope ratio may most likely be seen in soil samples from the solar pond area. Second, if unnatural ratios are seen in solar pond samples, then unnatural ratios may be expected in OU 11 as well because solar pond water was sprayed at the WSF.

The samples evaluated consist of 45 samples from OU 11 and 67 samples from the solar pond area. The solar pond samples indicate three samples with enriched uranium contamination levels greater than one half of one percent. However, none of the OU 11 samples exceed even this "low-level value" of contamination. Therefore, it can be stated conclusively that the soil at OU 11 contains natural uranium, not enriched uranium.

The RFP produced depleted uranium in addition to enriched uranium. Depleted uranium is by definition uranium which has less of the fissionable U^{235} than the approximate 0.7 percent by weight found in natural uranium. Depleted uranium is rich in the U^{238} isotope. Because the solar ponds received liquid waste from both depleted and enriched uranium processes, the uranium isotope ratios may be reflective of either depleted uranium (very high in U^{238}, very low in U^{234}) or enriched uranium (very high U^{235}, proportionately higher U^{234}, and lower U^{238}). A combination of contamination from both enriched and depleted uranium in a given soil sample would produce an isotopic ratio reflective of the relative amounts of both types of uranium. Although it is theoretically possible to have the exact relative amounts of both depleted and enriched uranium in one sample to produce an overall isotopic ratio that falls within the range of natural uranium, the likelihood of this occurring is extremely low. If both depleted uranium and enriched uranium are present, the ratio of U^{234} to U^{238} would be noticeably different than in natural uranium. As can be seen in Figure 1, the presence of an amount of enriched uranium as small as one percent of total uranium is strikingly noticeable. Isotopic analyses of uranium is very sensitive to small variations in the type of uranium present.

The analytical error in the measurement of uranium isotope activities in groundwater is such that the method described above yield inconclusive results. However, the source of unnatural materials at OU 11 was derived from the spray application of solar pond water. This sprayed water was applied only to the ground surface. Therefore any contamination of groundwater from

spray activities must have come from contaminated water percolating through subsurface soil. As demonstrated, uranium present in subsurface soil is from a natural source. It can be deduced that underlying groundwater could not be contaminated with enriched uranium if the subsurface soil does not contain uranium in enriched form.

TABLE A-1
URANIUM ISOTOPE RATIOS

Sample Number	Sample Location	Sample Depth	Sample Date	Sample Activity $U^{233,234}$	Sample Activity U^{238}	Calculated N $U^{233,234}$	Calculated N U^{238}	$U^{233,234}:U^{238}$
1A5	BZ-Surface	0	1986	1.1	0.89	3.92E+05	5.78E+09	6.78E-05
2A5	BZ-Surface	0	1986	1.2	1.2	4.28E+05	7.79E+09	5.49E-05
3A5	BZ-Surface	0	1986	1.4	1.2	4.99E+05	7.79E+09	6.40E-05
1B5	BZ-0-6"	0.5	1986	0.77	0.66	2.74E+05	4.29E+09	6.40E-05
2B5	BZ-0-6"	0.5	1986	0.86	0.92	3.06E+05	5.97E+09	5.13E-05
3B5	BZ-0-6"	0.5	1986	0.89	0.75	3.17E+05	4.87E+09	6.51E-05
1C5	BZ-6-12"	1	1986	0.67	0.62	2.39E+05	4.03E+09	5.93E-05
2C5	BZ-6-12"	1	1986	0.67	0.84	2.39E+05	5.45E+09	4.38E-05
3C5	BZ-6-12"	1	1986	0.66	0.76	2.35E+05	4.94E+09	4.77E-05
3D5	WSF-Surface	0	1986	1.2	0.9	4.28E+05	5.84E+09	7.32E-05
2D5	WSF-Surface	0	1986	1	1.1	3.56E+05	7.14E+09	4.99E-05
1D5	WSF-Surface	0	1986	1.1	1.2	3.92E+05	7.79E+09	5.03E-05
3E5	WSF-0-6"	0.5	1986	1	0.82	3.56E+05	5.32E+09	6.69E-05
2E5	WSF-0-6"	0.5	1986	0.74	1	2.64E+05	6.49E+09	4.06E-05
1E5	WSF-0-6"	0.5	1986	0.73	0.8	2.60E+05	5.19E+09	5.01E-05
3F5	WSF-6-12"	1	1986	0.83	0.82	2.96E+05	5.32E+09	5.56E-05
2F5	WSF-6-12"	1	1986	0.73	0.84	2.60E+05	5.45E+09	4.77E-05
1F5	WSF-6-12"	1	1986	0.59	0.61	2.10E+05	3.96E+09	5.31E-05
WSF0101	1'	1	1988	0.73	0.65	2.60E+05	4.22E+09	6.16E-05
WSF0102	2.5'	2.5	1988	0.85	0.84	3.03E+05	5.45E+09	5.55E-05
WSF0104	4.5'	4.5	1988	0.86	0.84	3.06E+05	5.45E+09	5.62E-05
WSF0201	0.9'	0.9	1988	0.82	0.79	2.92E+05	5.13E+09	5.70E-05
WSF0202	2.2'	2.2	1988	0.79	0.84	2.82E+05	5.45E+09	5.16E-05
WSF0204	4.4'	4.4	1988	1	1	3.56E+05	6.49E+09	5.49E-05
WSF0301	0.9'	0.9	1988	1.2	1.2	4.28E+05	7.79E+09	5.49E-05
WSF0302	2.2'	2.2	1988	0.91	0.85	3.24E+05	5.52E+09	5.88E-05
WSF0305	4.7'	4.7	1988	0.78	0.85	2.78E+05	5.52E+09	5.04E-05
WSF0401	0.9'	0.9	1988	0.89	0.85	3.17E+05	5.52E+09	5.75E-05
WSF0402	2.5'	2.5	1988	0.83	0.7	2.96E+05	4.55E+09	6.51E-05
WSF0404	4.1'	4.1	1988	0.92	0.9	3.28E+05	5.84E+09	5.61E-05
WSF0501	0.75'	0.7	1988	0.93	0.92	3.31E+05	5.97E+09	5.55E-05
WSF0502	2'	2	1988	1.4	1.3	4.99E+05	8.44E+09	5.91E-05
WSF0504	4.2'	4.2	1988	1.2	1.2	4.28E+05	7.79E+09	5.49E-05
WSF0601	0.7'	0.7	1988	0.83	0.81	2.96E+05	5.26E+09	5.62E-05
WSF0602	2.1'	2.1	1988	0.72	0.83	2.57E+05	5.39E+09	4.76E-05
WSF0604	4.6'	4.6	1988	0.76	0.83	2.71E+05	5.39E+09	5.03E-05
WSF0701	0.5'	0.5	1988	1.1	0.97	3.92E+05	6.30E+09	6.22E-05
WSF0702	2'	2	1988	1.2	0.94	4.28E+05	6.10E+09	7.01E-05
WSF0704	3.8'	3.8	1988	0.83	0.73	2.96E+05	4.74E+09	6.24E-05
WSF0801	0.65'	0.65	1988	0.96	0.97	3.42E+05	6.30E+09	5.43E-05
WSF0802	2'	2	1988	1.3	0.94	4.63E+05	6.10E+09	7.59E-05
WSF0805	4.6'	4.6	1988	0.92	0.98	3.28E+05	6.36E+09	5.15E-05
WSF0901	0.5'	0.5	1988	0.83	0.67	2.96E+05	4.35E+09	6.80E-05

TABLE 1
URANIUM ISOTOPE RATIOS

Sample Number	Sample Location	Sample Depth	Sample Date	Sample Activity $U^{233,234}$	Sample Activity U^{238}	Calculated N $U^{233,234}$	Calculated N U^{238}	$U^{233,234}:U^{238}$
WSF0902	2'	2	1988	1.6	1.4	5.70E+05	9.09E+09	6.27E−05
WSF0904	4'	4	1988	0.83	0.67	2.96E+05	4.35E+09	6.80E−05
WSF1001	0.5'	0.5	1988	0.83	0.82	2.96E+05	5.32E+09	5.56E−05
WSF1002	1.7'	1.7	1988	1.3	1.3	4.63E+05	8.44E+09	5.49E−05
WSF1004	3.5'	3.5	1988	1.1	0.96	3.92E+05	6.23E+09	6.29E−05
WSF1101	0.5'	0.5	1988	0.73	0.92	2.60E+05	5.97E+09	4.35E−05
WSF1102	2'	2	1988	0.95	0.82	3.39E+05	5.32E+09	6.36E−05
WSF1105	4.5'	4.5	1988	0.59	0.71	2.10E+05	4.61E+09	4.56E−05
WSF1201	0.5'	0.5	1988	1.3	1.4	4.63E+05	9.09E+09	5.10E−05
WSF1202	2'	2	1988	1.1	1.1	3.92E+05	7.14E+09	5.49E−05
WSF1205	4'	4	1988	1	0.94	3.56E+05	6.10E+09	5.84E−05
SP018705DH			1987	2	2.8	7.13E+05	1.82E+10	3.92E−05
SP018704DH			1987	1.7	2.1	6.06E+05	1.36E+10	4.44E−05
SP018711DH			1987	0.52	0.61	1.85E+05	3.96E+09	4.68E−05
SP018713DH			1987	0.4	0.54	1.43E+05	3.51E+09	4.07E−05
SP018716BR			1987	0.7	0.53	2.49E+05	3.44E+09	7.25E−05
SP018721DH			1987	0.57	0.71	2.03E+05	4.61E+09	4.41E−05
SP018723DH			1987	0.77	0.78	2.74E+05	5.06E+09	5.42E−05
SP02870008			1987	1.5	1.2	5.35E+05	7.79E+09	6.86E−05
SP028708UC			1987	0.58	0.49	2.07E+05	3.18E+09	6.50E−05
SP028713BR			1987	0.26	0.19	9.27E+04	1.23E+09	7.51E−05
SP028711CT			1987	0.54	0.55	1.92E+05	3.57E+09	5.39E−05
SP038711DH			1987	0.63	0.67	2.25E+05	4.35E+09	5.16E−05
SP038716BR			1987	0.77	0.7	2.74E+05	4.55E+09	6.04E−05
SP038713CT			1987	0.61	0.47	2.17E+05	3.05E+09	7.12E−05
SP0487004D			1987	0.63	0.66	2.25E+05	4.29E+09	5.24E−05
SP048707DH			1987	0.86	0.81	3.06E+05	5.26E+09	5.83E−05
SP048704DH			1987	1.1	0.86	3.92E+05	5.58E+09	7.02E−05
SP048702DH			1987	1.6	0.93	5.70E+05	6.04E+09	9.44E−05
SP048725DH			1987	1.1	1.2	3.92E+05	7.79E+09	5.03E−05
SP048730DH			1987	0.82	0.98	2.92E+05	6.36E+09	4.59E−05
SP048727DH			1987	0.58	0.7	2.07E+05	4.55E+09	4.55E−05
SP048712DH			1987	1.1	1	3.92E+05	6.49E+09	6.04E−05
SP048720DH			1987	1.1	1.2	3.92E+05	7.79E+09	5.03E−05
SP048722DH			1987	1.6	1.3	5.70E+05	8.44E+09	6.75E−05
SP048717DH			1987	1	1	3.56E+05	6.49E+09	5.49E−05
SP048732DH			1987	0.52	0.71	1.85E+05	4.61E+09	4.02E−05
SP058707DH			1987	0.5	0.39	1.78E+05	2.53E+09	7.04E−05
SP058702DH			1987	0.75	0.64	2.67E+05	4.16E+09	6.43E−05
SP058704DH			1987	0.76	0.64	2.71E+05	4.16E+09	6.52E−05
SP058710DH			1987	1.7	1.4	6.06E+05	9.09E+09	6.66E−05
SP058712DH			1987	1.2	0.92	4.28E+05	5.97E+09	7.16E−05
SP058716DH			1987	1.2	0.95	4.28E+05	6.17E+09	6.93E−05
SP068708DH			1987	0.52	0.59	1.85E+05	3.83E+09	4.84E−05

TABLE 1
URANIUM ISOTOPE RATIOS

Sample Number	Sample Location	Sample Depth	Sample Date	Sample Activity $U^{233,234}$	Sample Activity U^{238}	Calculated N $U^{233,234}$	Calculated N U^{238}	$U^{233,234}:U^{238}$
SP068711DH			1987	0.75	0.72	2.67E+05	4.68E+09	5.72E−05
SP068713DH			1987	0.5	0.38	1.78E+05	2.47E+09	7.22E−05
SP068718DH			1987	1.8	1.7	6.41E+05	1.10E+10	5.81E−05
SP068721DH			1987	1.2	1.6	4.28E+05	1.04E+10	4.12E−05
SP068716DH			1987	0.7	0.82	2.49E+05	5.32E+09	4.69E−05
SP068724DH			1987	1.4	1	4.99E+05	6.49E+09	7.68E−05
SP068726DH			1987	1.1	1.3	3.92E+05	8.44E+09	4.64E−05
SP078711DH			1987	0.97	0.91	3.46E+05	5.91E+09	5.85E−05
SP078713DH			1987	0.47	0.62	1.67E+05	4.03E+09	4.16E−05
SP078721CT			1987	1.5	1.6	5.35E+05	1.04E+10	5.15E−05
SP078711DH			1987	0.42	0.5	1.50E+05	3.25E+09	4.61E−05
SP078702DH			1987	0.6	0.56	2.14E+05	3.64E+09	5.88E−05
SP078716DH			1987	0.6	0.41	2.14E+05	2.66E+09	8.03E−05
SP078726DH			1987	1.1	1.2	3.92E+05	7.79E+09	5.03E−05
SP078723BR			1987	1.2	1.6	4.28E+05	1.04E+10	4.12E−05
SP078718WT			1987	0.88	0.7	3.14E+05	4.55E+09	6.90E−05
SP098703UC			1987	0.45	0.43	1.60E+05	2.79E+09	5.74E−05
SP098708BR			1987	0.84	0.91	2.99E+05	5.91E+09	5.07E−05
SP098706CT			1987	0.94	1.1	3.35E+05	7.14E+09	4.69E−05
SP108700DH			1987	1.4	0.67	4.99E+05	4.35E+09	1.15E−04
SP108715DH			1987	0.63	0.7	2.25E+05	4.55E+09	4.94E−05
SP108713DH			1987	0.45	0.73	1.60E+05	4.74E+09	3.38E−05
SP108711DH			1987	0.49	0.64	1.75E+05	4.16E+09	4.20E−05
SP108709DH			1987	1	0.97	3.56E+05	6.30E+09	5.66E−05
SP108707DH			1987	0.66	0.59	2.35E+05	3.83E+09	6.14E−05
SP108705DH			1987	1	0.68	3.56E+05	4.42E+09	8.07E−05
SP108704BR			1987	1.6	0.68	5.70E+05	4.42E+09	1.29E−04
SP108702DH			1987	3.7	0.88	1.32E+06	5.71E+09	2.31E−04
SP1087017D			1987	0.6	0.65	2.14E+05	4.22E+09	5.07E−05
SP108717DH			1987	1	0.96	3.56E+05	6.23E+09	5.72E−05
SP108721WT			1987	1.1	0.99	3.92E+05	6.43E+09	6.10E−05
SP108719DH			1987	1.4	1.4	4.99E+05	9.09E+09	5.49E−05
SP108723DH			1987	1.2	1.1	4.28E+05	7.14E+09	5.99E−05
SP108724DH			1987	0.48	0.58	1.71E+05	3.77E+09	4.54E−05

FIGURE 1

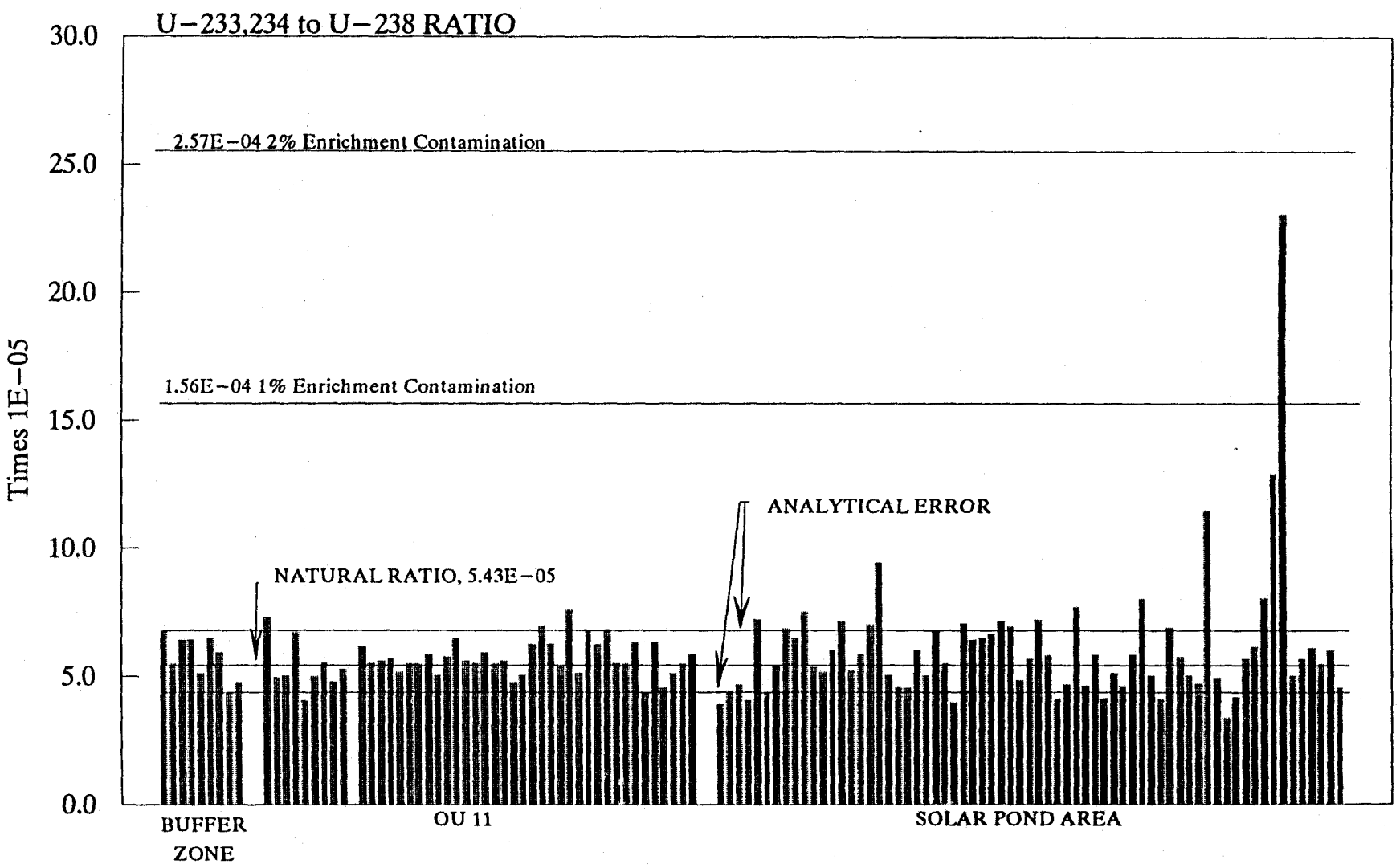
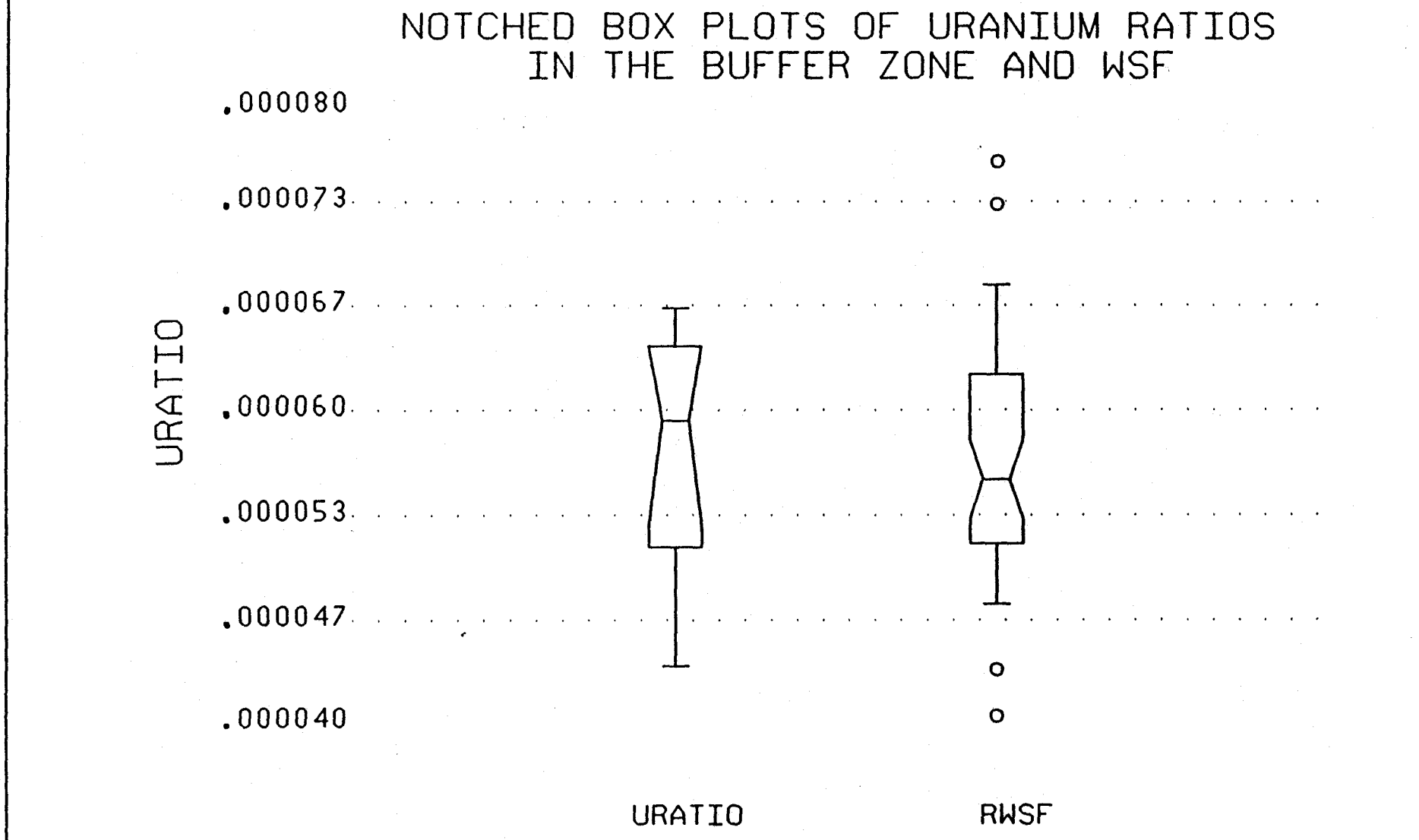

U−233,234 to U−238 RATIO
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Times 1E−05
2.57E−04 2% Enrichment Contamination
1.56E−04 1% Enrichment Contamination
ANALYTICAL ERROR
NATURAL RATIO, 5.43E−05
BUFFER ZONE
OU 11
SOLAR POND AREA

FIGURE 2


NOTCHED BOX PLOTS OF URANIUM RATIOS
IN THE BUFFER ZONE AND WSF
.000080
.000073
.000067
.000060
.000053
.000047
.000040
URATIO
URATIO
RWSF

APPENDIX B

MATHEMATICAL ANALYTICAL MODEL

APPENDIX B

MATHEMATICAL ANALYTICAL MODEL

West Spray Field, Rocky Flats Plant

Project Objective

The objective of this groundwater project is to evaluate the influence of spray application on the water table underlying the West Spray Field of Rocky Flats Plant (RFP). This paper presents an analytical two dimensional model which has been applied to the West Spray Field parameters.

Background

For a period of approximately 4 1/2 years, from April, 1982 to October, 1985, spray irrigation was employed to evaporate RFP waste water. The West Spray Field, which was identified as a RCRA hazardous waste management unit in 1986, includes an area of approximately 105 acres. Initially, application was performed using two moving irrigation lines mounted on metal wheels; later these portable lines were replaced by fixed lines.

Three areas received irrigation. The location and size of the three areas as well as the approximate location of the fixed lines are shown in Figure 1-1 in Section 1 of this Technical Memorandum. According to recent estimates, approximately 66,000,000 gallons of waste water were applied at variable rates of 0 to 450 gallons per minute. The width of each spray line was 80 feet.

Geologic/Hydrogeologic Setting

The West Spray Field is situated on top of the Rocky Flats Alluvium unconfined aquifer. This heterogeneous alluvial fan deposit is composed of gravel, sand, and clay layers and lenses. The overall thickness of the formation in the West Spray Field area is approximately 70 feet, and the average depth to water is approximately 50 feet. However, historical and recent drilling data in the West Spray Field area have revealed that one or more perched water layers are present. This study will model the configuration of one such perched mound.

The Rocky Flats Alluvium has been pump tested in other areas of Rocky Flats. Hydraulic conductivities from those tests were assumed to be representative and were used in the analytical model.

Analytical Model

The analytical model was derived from a paper entitled "Hydrodynamics of Perched Mounds", (Brock 1976) in which models for transient and steady state mound development are presented. Equations for three basin shapes: strip, circular, and square, are given; equations representing the strip basin steady state solution were applied to the West Spray Field Area 1. The physical model consists of a shallow subsurface groundwater mound developing on top of a clay layer within the Rocky Flats Alluvium aquifer.

Hydrologic Assumptions

The following assumptions are inherent to the analytical solutions:

1. Only saturated flow occurs within the perched mound.
2. The material above the semipervious layer is homogeneous and isotropic.
3. The pressure distribution is hydrostatic within the perched mound.
4. The pressure is atmospheric just below the semipervious layer.
5. Recharge to the aquifer was applied uniformly and at a constant rate over the recharge basin.

Analytical Solution Equations

Although there is no exact analytical solution for the steady state model presented by Brock, there is a close approximation consisting of five equations. Solving the equations yields values of the maximum height and lateral extent of the mound for a set of input parameters. The five equations and definition of symbols are presented below.

eq 1.) $a = (p_0' - K_L') - (K_L'/b')H_0'$

a is calculated in terms of H_0' and substituted into equation 2.

eq 2.) $(H_0'^2 - a)^{3/2} + 3/2\ b'\ (H_0'^2 - a) = 3/2\ (b'/K_L')\ a^2$

The value of H_0' is found and substituted into equation 3.

eq 3.) $H'^2 = H_0'^2 - a\ x'^2$

Equation 3 is solved for $H' = H_1'$; $x' = x/L = 1$

eq 4.) $H' = 1/6\ (K_L'/b')\ (c - x')^2 - (3/2)\ b'$

The value of H_1' determined in equation 3 and the value of $x' = 1$ are used in equation 4 to determine a value for c.

eq 5.) $x'_{max} = c - 3\ (b'/K_L')^{1/2}$

Equation 5 yields x'_{max}. With H_0' and c known, H' versus x' can be found.

Definition of Terms

b = thickness of semipervious layer; b' - b/L
H = thickness of mound; H' = H/L
H_0 = H at center of basin; $H_0' = H_0/L$ at X'= 0
H_1 = H at edge of basin; $H_1' = H_1/L$ at x' = 1
K = permeability above layer
K_L = permeability of layer; $K_L' = K_L/K$
L = half width of strip basin
p_0 = recharge rate for x < L (volume/time/area)
x = distance from center of strip; x' = x/L
x'_{max}= x' at which H' = o or dimensionless length of mound.

Parameters Used

K = .445 ft./day
K_L = .004 ft./day
b = 2.5 feet
L = 400 feet
p_0 = .015 $ft^3/day/ft^2$

p_0 was estimated using the following information:

Total volume of water applied = 66,000,000 gal.

Total days applied = 547.5 (It was assumed that during the 4 1/2 years irrigation was practiced, water was applied 1/3 of the time.)

Using the information above, the average P_0 was calculated to be .0102 ft./day. However the equations were yielding invalid results when this low rate was used. By trial and error, it was determined that P_0 = .015 ft./day was the lowest rate that could be entered to the equations if the other parameters were held constant. P_0 = .015 ft./day was considered to be a reasonable average infiltration rate and was used.

Calculated Results

H_0 = 6.80 feet H_0' = .01699

H_1 = 0.97 feet H_1' = .002430

x_{max} = 409.6 feet x'_{max} = 1.024

a = .0002828
c = 1.2219

Values for the construction of a two dimensional mound profile were calculated; the mound cross sectional profile is attached (Figure A-1). The line of section for the mound is also shown on the map of the West Spray Field in Figure 3-2 in Section 3 of this Technical Memorandum.

Discussion of Results

The above results were calculated using assumed values for K, K_L, b, and P_0. According to this analysis, the maximum height of subsurface groundwater mound development at steady state is 6.8 feet. Two numerical analyses, one for steady state flow and one for transient flow, yielded similar results in terms of mound thickness. However in the numerical analyses, the effect of varying K and b values were also investigated. In addition, the transient numerical model included the entire West Spray Field rather than only Area 1. The significance of these studies in light of the field sampling plan is that subsurface groundwater mounds under the West Spray Field are relatively thin. Good core recovery is critical to the characterization program.

Figure B-1 East-West Profile of Mound Across Area 1

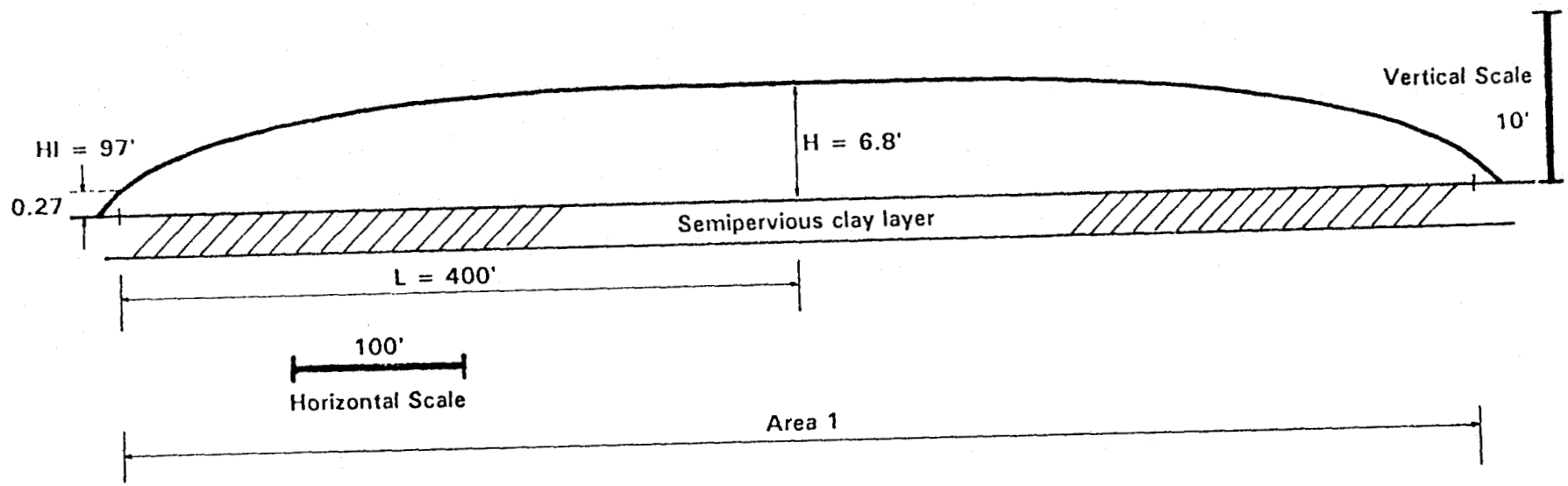


TABLE B-1 CALCULATED EAST-WEST PROFILE OF MOUND ACROSS AREA 1

Data Calculated for Mound Profile

x	x'	H'	H
(H_0)	0	.01699	6.80
50'	.125	.01686	6.74'
100'	.25	.01646	6.58'
150'	.375	.01578	6.31'
200'	.5	.01476	5.90'
250'	.625	.01334	5.34'
300'	.75	.01138	4.55'
350'	.875	.00849	3.40'
400' (H_1)	1.0	.002421	0.97
409.6' x_{max}			0

APPENDIX C

CONTAMINANTS OF CONCERN TABLES

TABLE C-1
SELECTION OF POTENTIAL CONSTITUENTS OF CONCERN FOR OU 11
ALLUVIAL GROUNDWATER

Analyte	Units	Sample Type	Sample Number	Sample Mean	Max Detected Value	Background Mean	p-Value (Gehan Method)	Detection Frequency (%)	Nutrient (Y/N)	ARAR	PRG	PCOC (Y/N)
Metals												
Aluminum	ug/L	Total	46	11,237.99	208,000.00	6,239.42	0.035	93.5	N	50-200(a)	ND	Y
Iron	ug/L	Total	46	10,692.18	198,000.00	8,215.92	0.033	95.7	Y			N
Manganese	ug/L	Total	46	256.33	2,710.00	165.77	0.020	93.5	N	50(a)	180	Y
Sodium	ug/L	Total	46	13,457.83	21,200.00	7,547.90	0.000	100.0	Y			N
Mercury	ug/L	Dissolved	46	0.11	0.24	0.10	0.016	10.9	N	2.0(b)	11	N
Silicon	ug/L	Dissolved	33	10,838.79	14,300.00	8,614.58	0.021	100.0	N	NA	NA	N(c)
Sodium	ug/L	Dissolved	46	13,124.57	20,800.00	7,611.54	0.000	100.0	Y			N
Antimony	ug/L	Total	46	11.28	17.20	21.15	0.999	2.2				N
Arsenic	ug/L	Total	45	1.29	1.80	1.20	0.930	20.0				N
Barium	ug/L	Total	46	108.82	1,040.00	123.20	0.841	91.3				N
Beryllium	ug/L	Total	46	1.33	16.40	0.82	0.941	2.2				N
Cadmium	ug/L	Total	46	1.24	1.30	1.22	0.994	2.2				N
Calcium	ug/L	Total	46	23,390.22	62,200.00	34,036.84	0.998	100.0				N
Chromium	ug/L	Total	46	14.04	208.00	14.43	0.742	45.7				N
Cobalt	ug/L	Total	46	7.04	68.00	5.02	0.684	21.7				N
Copper	ug/L	Total	46	11.15	191.00	12.49	0.869	23.9				N
Lead	ug/L	Total	46	4.57	59.80	6.58	0.805	76.1				N
Lithium	ug/L	Total	46	12.97	134.00	8.79	0.998	34.8				N
Magnesium	ug/L	Total	46	6,156.96	37,000.00	5,295.26	0.218	95.7				N
Molybdenum	ug/L	Total	46	15.02	3.80	2.90	0.998	6.5				N
Nickel	ug/L	Total	46	15.46	155.00	14.16	0.405	58.7				N
Potassium	ug/L	Total	46	2,045.11	25,200.00	1,455.35	0.059	78.3				N
Silicon	ug/L	Total	33	23,336.36	135,000.00	13,100.00	0.115	100.0				N
Silver	ug/L	Total	46	1.87	9.40	1.73	0.980	2.2				N
Strontium	ug/L	Total	45	126.96	252.00	133.54	0.651	88.9				N
Thallium	ug/L	Total	46	1.15	1.00	0.65	0.994	2.2				N
Tin	ug/L	Total	46	23.26	39.40	11.64	0.747	2.2				N
Vanadium	ug/L	Total	46	21.28	349.00	17.29	0.358	47.8				N
Zinc	ug/L	Total	46	32.29	405.00	64.73	0.816	43.5				N
Aluminum	ug/L	Dissolved	42	64.02	1,030.00	201.92	0.999	23.8				N
Antimony	ug/L	Dissolved	46	12.71	26.30	15.33	0.967	10.9				N
Barium	ug/L	Dissolved	46	51.05	87.20	68.01	1.000	84.8				N
Cadmium	ug/L	Dissolved	46	1.21	NA	1.42	0.995	0.0				N
Calcium	ug/L	Dissolved	46	21,841.96	39,400.00	32,205.60	1.000	100.0				N
Chromium	ug/L	Dissolved	46	2.22	3.10	4.78	1.000	2.2				N
Cobalt	ug/L	Dissolved	46	4.83	6.50	3.94	0.878	2.2				N
Copper	ug/L	Dissolved	46	2.73	2.30	4.05	1.000	6.5				N
Iron	ug/L	Dissolved	43	105.30	1,730.00	221.75	0.908	34.9				N
Lead	ug/L	Dissolved	46	0.81	1.50	1.58	0.992	4.3				N
Lithium	ug/L	Dissolved	45	8.94	7.10	7.64	1.000	31.3				N
Magnesium	ug/L	Dissolved	46	4,469.57	9,820.00	4,102.23	0.415	91.3				N
Manganese	ug/L	Dissolved	46	88.67	1,380.00	7.59	0.952	43.5				N
Molybdenum	ug/L	Dissolved	45	15.10	2.60	6.84	1.000	2.2				N
Nickel	ug/L	Dissolved	46	5.31	5.70	6.33	1.000	13.0				N

TABLE C-1
SELECTION OF POTENTIAL CONSTITUENTS OF CONCERN FOR OU 11
ALLUVIAL GROUNDWATER

Analyte	Units	Sample Type	Sample Number	Sample Mean	Max Detected Value	Background Mean	p-Value (Gehan Method)	Detection Frequency (%)	Nutrient (Y/N)	ARAR	PRG	PCOC (Y/N)
Potassium	ug/L	Dissolved	46	773.15	1,360.00	657.27	0.536	41.3				N
Selenium	ug/L	Dissolved	46	0.85	1.60	16.06	0.896	6.5				N
Silver	ug/L	Dissolved	46	1.71	NA	269.36	1.000	0.0				N
Strontium	ug/L	Dissolved	46	122.88	236.00	265.56	0.738	89.1				N
Thallium	ug/L	Dissolved	46	1.21	NA	3.46	0.991	0.0				N
Tin	ug/L	Dissolved	46	22.24	11.20	19.04	1.000	2.2				N
Vanadium	ug/L	Dissolved	45	4.97	3.90	5.10	1.000	17.8				N
Zinc	ug/L	Dissolved	46	5.69	19.10	17.48	1.000	19.6				N
Mercury	ug/L	Total	46	0.11	0.24	0.11	0.465	6.5				N
Selenium	ug/L	Total	45	0.86	1.00	1.00	0.500	6.7				N
Arsenic	ug/L	Dissolved	46	1.22	0.80	1.06	0.500	2.2				N
Beryllium	ug/L	Dissolved	46	0.97	NA	0.76	0.929	0.0				N
Cesium	ug/L	Dissolved	38	127.82	NA	124.11	0.927	0.0				N
Cesium	ug/L	Total	36	135.03	NA	24.22	NA	0.0				N
Radionuclides												
Gross Alpha	ug/L	Dissolved	42	1.28	14.88	0.60	0.003		N		NA	N(d)
Uranium-233,234	ug/L	Dissolved	38	0.57	7.74	0.18	0.004		N		3	N(e)
Uranium-238	ug/L	Dissolved	38	0.44	6.76	0.13	0.001		N		3	N(e)
Gross Beta	ug/L	Dissolved	46	1.75	6.96	1.83	0.498					N
Strontium-89,90	ug/L	Dissolved	46	0.34	1.30	0.26	0.261					N
Uranium-235	ug/L	Dissolved	38	0.04	0.28	0.03	0.373					N
Americium-241	ug/L	Total	42	0.01	0.16	0.00	0.727					N
Cesium-137	ug/L	Total	31	0.09	0.86	0.13	0.534					N
Plutonium-239/240	ug/L	Total	41	0.01	0.25	0.00	0.081					N
Tritium	ug/L	Total	46	146.39	1,535.00	362.50	0.997					N
WQ Parameters												
Chloride	mg/L		35	7.50	15.00	5.24	0.000		N	250	NA	N
Fluoride	mg/L		46	0.55	2.50	0.77	0.009		N	2	NA	N
Nitrate/Nitrite	mg/L		46	1.69	7.30	1.51	0.955					N
Sulfate	mg/L		46	11.89	35.60	24.17	1.000					N
Cyanide	mg/L		42	0.00	0.00	0.01	NA	2.4				N

ENDNOTES:

The calculation of the sample mean quantifies each non-detect as a value equal to half the detection limit. For samples with the max value less than the detection level, the value of the mean may exceed the value of the max.

ND = No toxicity data available for derivation of PRG

NA = Not applicable

ARAR = Applicable or Relevant and Appropriate Requirement

PRG = Preliminary Remediation Goals

(a) Secondary drinking water standard

(b) Primary drinking water standard

(c) Major constituent of Earth's crust

(d) Not an anaylte used for comparison

(e) Natural uranium source; not contamination from RFP see section 4.2.2.1

1) Number of decimal places do not present scientifically valid significant figures

2) p-Value is a statisically derived value for comparison of a sample to background:
p-Value ≤ 0.05 - Sample is statisically significantly higher than background
p-Value > 0.05 - Sample is not statistically different from background

3) See text for development of ARARs and PRGs

TABLE C-2
SELECTION OF POTENTIAL CONSTITUENTS OF CONCERN FOR OU 11
BEDROCK GROUNDWATER

Analyte	Units	Sample Type	Sample Number	Sample Mean	Max Detected Value	Background Mean	p-Value (Gehan Method)	Detection Frequency (%)	Nutrient (Y/N)	ARAR	PRG	PCOC (Y/N)
Metals												
Barium	ug/L	Total	8	167.50	289.00	374.87	0.047	100.0	N	1000(a)	2600	N
Chromium	ug/L	Total	8	25.35	41.30	272.23	0.034	100.0	N	50(a)	180	N
Vanadium	ug/L	Dissolved	8	13.04	25.00	7.47	0.033	62.5	N	260(a)	260	N
Aluminum	ug/L	Total	8	5,852.48	15,300.00	2,546.67	0.326	87.5				N
Antimony	ug/L	Total	8	9.19	NA	277.12	0.915	0.0				N
Arsenic	ug/L	Total	8	1.88	3.6	4.60	0.993	87.5				N
Beryllium	ug/L	Total	8	0.76	NA	27.17	0.876	0.0				N
Cadmium	ug/L	Total	8	1.16	1.10	287.97	0.964	12.5				N
Calcium	ug/L	Total	8	36,737.50	67,000.00	34,583.33	0.122	100.0				N
Cobalt	ug/L	Total	8	4.38	10.30	273.02	0.625	37.5				N
Copper	ug/L	Total	8	7.91	20.00	300.06	0.746	50.0				N
Iron	ug/L	Total	8	6,278.00	14,000.00	3,619.13	0.398	100.0				N
Lead	ug/L	Total	8	5.06	15.00	5.38	0.553	87.5				N
Lithium	ug/L	Total	8	16.74	26.60	46.83	0.985	75.0				N
Magnesium	ug/L	Total	8	6,997.50	11,100.00	6,945.00	0.151	100.0				N
Manganese	ug/L	Total	8	170.25	331.00	179.23	0.123	100.0				N
Molybdenum	ug/L	Total	8	28.03	53.10	276.14	0.251	87.5				N
Nickel	ug/L	Total	8	23.11	40.10	285.58	0.126	100.0				N
Potassium	ug/L	Total	8	4,170.00	5,060.00	3,216.67	0.061	100.0				N
Selenium	ug/L	Total	8	0.76	1.30	1.08	0.831	12.5				N
Silicon	ug/L	Total	8	18,300.00	38,400.00	8,905.00	0.159	100.0				N
Silver	ug/L	Total	8	1.20	NA	51.72	0.876	0.0				N
Sodium	ug/L	Total	8	29,400.00	44,800.00	172,350.00	0.999	100.0				N
Strontium	ug/L	Total	8	369.88	484.00	420.50	0.151	100.0				N
Thallium	ug/L	Total	8	0.59	NA	0.70	0.894	0.0				N
Tin	ug/L	Total	8	12.13	15.20	20.38	0.213	12.5				N
Vanadium	ug/L	Total	8	26.44	63.30	288.32	0.554	75.0				N
Zinc	ug/L	Total	8	35.94	84.50	368.88	0.949	62.5				N
Aluminum	ug/L	Dissolved	8	14.46	31.80	42.16	0.962	25.0				N
Antimony	ug/L	Dissolved	8	9.55	10.00	14.97	0.838	12.5				N
Arsenic	ug/L	Dissolved	8	1.48	2.20	3.56	1.000	87.5				N
Barium	ug/L	Dissolved	8	88.40	144.00	68.17	0.288	100.0				N
Calcium	ug/L	Dissolved	8	28,187.50	33,300.00	33,752.63	0.144	100.0				N
Cesium	ug/L	Dissolved	7	83.57	30.00	88.34	0.769	14.3				N
Chromium	ug/L	Dissolved	8	1.68	NA	5.08	0.959	0.0				N
Copper	ug/L	Dissolved	8	0.93	NA	4.58	0.992	0.0				N
Iron	ug/L	Dissolved	8	35.06	210.00	26.08	0.858	25.0				N
Lead	ug/L	Dissolved	8	0.54	NA	1.49	0.936	0.0				N
Lithium	ug/L	Dissolved	8	11.84	26.30	49.11	0.999	50.0				N
Magnesium	ug/L	Dissolved	8	3,808.25	7,790.00	6,276.32	0.920	100.0				N
Manganese	ug/L	Dissolved	8	54.21	171.00	8.40	0.366	62.5				N
Molybdenum	ug/L	Dissolved	8	27.41	52.70	18.15	0.241	62.5				N
Nickel	ug/L	Dissolved	8	3.71	NA	5.18	0.845	0.0				N
Potassium	ug/L	Dissolved	8	3,000.00	4,230.00	3,379.74	0.768	100.0				N
Selenium	ug/L	Dissolved	8	0.68	1.20	1.97	0.913	12.5				N

TABLE C-2
SELECTION OF POTENTIAL CONSTITUENTS OF CONCERN FOR OU 11
BEDROCK GROUNDWATER

Analyte	Units	Sample Type	Sample Number	Sample Mean	Max Detected Value	Background Mean	p-Value (Gehan Method)	Detection Frequency (%)	Nutrient (Y/N)	ARAR	PRG	PCOC (Y/N)
Silicon	ug/L	Dissolved	6	3,835.00	4,470.00	3,536.67	0.261	100.0				N
Silver	ug/L	Dissolved	8	1.20	NA	3.37	0.964	0.0				N
Sodium	ug/L	Dissolved	8	29,525.00	44,800.00	194,115.79	1.000	100.0				N
Strontium	ug/L	Dissolved	8	313.38	462.00	450.40	0.144	100.0				N
Thallium	ug/L	Dissolved	8	0.78	1.00	1.37	0.097	12.5				N
Tin	ug/L	Dissolved	8	10.58	NA	18.18	0.921	0.0				N
Zinc	ug/L	Dissolved	8	2.73	4.30	11.88	0.994	25.0				N
Cadmium	ug/L	Dissolved	8	1.09	NA	1.33	0.767	0.0				N
Cobalt	ug/L	Dissolved	8	1.70	NA	4.63	0.708	0.0				N
Mercury	ug/L	Dissolved	8	0.10	NA	0.11	0.784	0.0				N
Cesium	ug/L	Total	7	81.43	NA	56.83	NA	0.0				N
Mercury	ug/L	Total	8	0.10	NA	0.10	NA	0.0				N
Beryllium	ug/L	Dissolved	8	0.73	NA	0.83	NA	0.0				N
Radionuclides												
Gross Alpha	ug/L	Dissolved	7	1.49	2.60	3.37	0.668					N
Gross Beta	ug/L	Dissolved	8	3.37	4.47	4.02	0.333					N
Radium-226	ug/L	Dissolved	2	0.23	0.30	2.98	0.730					N
Strontium-89,90	ug/L	Dissolved	8	0.43	1.09	0.38	0.479					N
Uranium-233,234	ug/L	Dissolved	6	0.47	1.50	1.83	0.966					N
Uranium-235	ug/L	Dissolved	6	0.06	0.18	0.05	0.683					N
Uranium-238	ug/L	Dissolved	6	0.30	1.10	0.57	0.895					N
Americium-241	ug/L	Total	7	0.00	0.01	0.01	0.797					N
Cesium-137	ug/L	Total	5	0.23	0.58	0.00	0.122					N
Plutonium-239/240	ug/L	Total	6	0.01	0.03	0.00	0.228					N
Tritium	ug/L	Total	8	123.51	352.60	400.00	0.912					N
WQ Parameters												
Chloride	mg/L		7	6.43	13.00	103.03	0.912	86.2				N
Fluoride	mg/L		8	1.05	1.40	1.20	0.809	100.0				N
Nitrate/Nitrite	mg/L		8	0.02	0.03	1.21	1.000	84.0				N
Sulfate	mg/L		8	56.69	128.00	203.88	0.669	96.4				N

ENDNOTES:

The calculation of the sample mean quantifies each non-detect as a value equal to half the detection limit. For samples with the max value less than the detection level, the value of the mean may exceed the value of the max.

NA = Not Applicable

ARAR = Applicable or Relevant and Appropriate Requirement

PRG = Preliminary Remediation Goals

(a) Primary drinking water standard

1) Number of decimal places do not present scientifically valid significant figures
2) p-Value is a statisically derived value for comparison of a sample to background:
   p-Value ≤ 0.05 - Sample is statisically significantly higher than background
   p-Value > 0.05 - Sample is not statistically different from background
3) See text for development of ARARs and PRGs

TABLE C-3
SELECTION OF POTENTIAL CONSTITUENTS OF CONCERN FOR OU 11
SURFACE WATER

Analyte	Units	Sample Type	Sample Number	Sample Mean	Max Detected Value	Background Mean	p-Value (Gehan Method)	Detection Frequency (%)	Nutrient (Y/N)	ARAR	PRG	PCOC (Y/N)
Metals												
Sodium	ug/L	Total	8	18,070.00	28,900.00	12,819.00	0.011	100.0	Y			N
Thallium	ug/L	Total	7	NA	NA	2.46	NA	0.0				N
Aluminum	ug/L	Total	8	738.50	2,080.00	19,557.35	0.992	87.5				N
Antimony	ug/L	Total	7	18.27	NA	47.08	0.852	0.0				N
Arsenic	ug/L	Total	8	3.39	7.80	76.79	0.976	12.5				N
Barium	ug/L	Total	8	70.39	130.00	981.32	0.998	50.0				N
Berylium	ug/L	Total	7	1.30	NA	2.84	0.909	0.0				N
Cadmium	ug/L	Total	7	1.96	NA	9.67	0.915	0.0				N
Calcium	ug/L	Total	8	12,032.50	23,000.00	100,451.02	1.000	100.0				N
Cesium	ug/L	Total	7	305.00	60.00	430.82	0.731	28.6				N
Chromium	ug/L	Total	8	3.78	4.30	25.01	0.957	25.0				N
Cobalt	ug/L	Total	7	12.83	9.00	45.75	0.820	28.6				N
Copper	ug/L	Total	7	8.83	11.60	47.04	0.915	42.9				N
Iron	ug/L	Total	8	1,167.00	3,900.00	186,477.87	0.947	100.0				N
Lead	ug/L	Total	8	5.60	6.00	97.84	0.957	62.5				N
Lithium	ug/L	Total	7	30.30	2.10	31.78	0.971	14.3				N
Magnesium	ug/L	Total	8	2,681.25	6,100.00	10,896.70	1.000	50.0				N
Manganese	ug/L	Total	8	141.64	830.00	1,916.62	0.783	100.0				N
Mercury	ug/L	Total	7	0.14	0.37	0.15	0.359	14.3				N
Molybdenum	ug/L	Total	7	33.79	NA	38.63	0.818	0.0				N
Nickel	ug/L	Total	7	12.32	10.40	49.07	0.791	42.9				N
Potassium	ug/L	Total	8	4,615.00	3,900.00	3,586.20	0.128	62.5				N
Selenium	ug/L	Total	8	2.01	2.80	2.40	0.457	12.5				N
Silicon	ug/L	Total	1	6,310.00	6,310.00	7,825.00	0.781	100.0				N
Silver	ug/L	Total	7	3.75	4.40	10.32	0.771	28.6				N
Strontium	ug/L	Total	7	319.13	160.00	538.18	0.983	42.9				N
Tin	ug/L	Total	7	33.07	NA	104.03	0.927	0.0				N
Vanadium	ug/L	Total	7	12.23	4.90	120.60	0.981	28.6				N
Zinc	ug/L	Total	8	45.75	118.00	208.78	0.873	75.0				N
Radionuclides												
Gross Alpha	ug/L	Dissolved	1	1.15	1.15	3.32	0.614					N
Gross Beta	ug/L	Dissolved	1	12.53	12.53	6.02	0.115					N
Strontium-89,90	ug/L	Dissolved	1	1.44	1.44	0.42	0.068					N
Uranium-233,-234	ug/L	Dissolved	1	0.26	0.26	0.91	0.772					N
Uranium-235	ug/L	Dissolved	1	0.05	0.05	0.12	0.657					N
Uranium-238	ug/L	Dissolved	1	0.21	0.21	0.61	0.772					N
Americium-241	ug/L	Total	4	0.00	0.01	0.01	0.917					N
Cesium-137	ug/L	Total	4	0.00	0.54	0.60	0.875					N
Gross Alpha	ug/L	Total	3	0.93	2.52	46.89	0.964					N
Gross Beta	ug/L	Total	3	6.02	8.00	50.40	0.476					N
Plutonium-239/240	ug/L	Total	4	0.01	0.01	0.20	0.751					N
Strontium-89,90	ug/L	Total	3	0.56	0.90	0.31	0.091					N
Tritium	ug/L	Total	2	123.25	186.50	156.93	0.642					N
Uranium, total	ug/L	Total	1	0.00	0.00	0.86	0.919					N

TABLE C-3
SELECTION OF POTENTIAL CONSTITUENTS OF CONCERN FOR OU 11
SURFACE WATER

Analyte	Units	Sample Type	Sample Number	Sample Mean	Max Detected Value	Background Mean	p-Value (Gehan Method)	Detection Frequency (%)	Nutrient (Y/N)	ARAR	PRG	PCOC (Y/N)
Uranium-233,234	ug/L	Total	3	0.05	0.09	0.65	0.984					N
Uranium-235	ug/L	Total	3	0.00	0.00	0.02	0.770					N
Uranium-238	ug/L	Total	3	0.02	0.04	0.64	0.980					N

ENDNOTES:

The calculation of the sample mean quantifies each non-detect as a value equal to half the detection limit. For samples with the max value less than the detection level, the value of the mean may exceed the value of the max.

NA = Not Applicable

ARAR = Applicable or Relevant and Appropriate Requirement

PRG = Preliminary Remediation Goals

1) Number of decimal places do not present scientifically valid significant figures
2) p-Value is a statisically derived value for comparison of a sample to background:
   p-Value ≤ 0.05 - *Sample* is statisically significantly higher than background
   p-Value > 0.05 - Sample is not statistically different from background
3) See text for development of ARARs and PRGs

TABLE C-4
SELECTION OF POTENTIAL CONSTITUENTS OF CONCERN FOR OU 11
SURFACE SOILS

Analyte	Units	Sample Type	Sample Number	Sample Mean	Max Detected Value	Background Mean	p-Value (Gehan Method)	Detection Frequency (%)	Nutrient (Y/N)	ARAR	PRG	PCOC (Y/N)
Metals												
Lead	mg/kg		12	16.15	26.00	36.02	1.000	100.0				N
Mercury	mg/kg		12	0.18	NA	NA	NA	8.3				N
Radionuclides												
Gross Alpha	pCi/g		12	11.67	30.00	10.75	0.500	100.0				N
Gross Beta	pCi/g		12	23.50	38.00	33.31	0.977	100.0				N
Plutonium-239/240	pCi/g		12	0.15	0.59	0.05	0.900	100.0				N
Uranium-233,234	pCi/g		12	0.93	1.30	1.22	0.997	100.0				N
Uranium-238	pCi/g		12	0.91	1.40	1.32	0.998	100.0				N
Other												
Nitrate/Nitrite	mg/kg		12	60.00	NA	2.26	0.245	8.3				N

ENDNOTES:

The calculation of the sample mean quantifies each non-detect as a value equal to half the detection limit. For samples with the max value less than the detection level, the value of the mean may exceed the value of the max.

NA = Not Applicable

ARAR = Applicable or Relevant and Appropriate Requirement

PRG = Preliminary Remediation Goals

1) Number of decimal places do not present scientifically valid significant figures
2) p-Value is a statisically derived value for comparison of a sample to background:
   p-Value ≤ 0.05 - Sample is statisically significantly higher than background
   p-Value > 0.05 - Sample is not statistically different from background
3) See text for development of ARARs and PRGs

TABLE C-5
SELECTION OF POTENTIAL CONSTITUENTS OF CONCERN FOR OU 11
SUBSURFACE SOILS

Analyte	Units	Sample Type	Sample Number	Sample Mean	Max Detected Value	Background Mean	p-Value (Gehan Method)	Detection Frequency (%)	Nutrient (Y/N)	ARAR	PRG	PCOC (Y/N)
Metals												
Lead	mg/kg		24	12.51	24.00	8.82	0.000	100.0	N	500		N
Mercury	mg/kg		22	0.16	0.46	0.18	0.245	72.7				N
Radionuclides												
Gross Alpha	pCi/g		24	12.88	39.00	21.82	1.000	100.0				N
Gross Beta	pCi/g		23	24.83	36.00	23.89	0.200	100.0				N
Plutonium-239/240	pCi/g		23	0.03	0.25	0.00	0.000	100.0	N		0.011	Y
Uranium, Total	pCi/g		24	1.89	3.00	1.28	0.000	100.0	N			N(a)
Uranium-233,234	pCi/g		24	0.99	1.60	0.64	0.000	100.0	N		0.0069	N(a)
Uranium-238	pCi/g		24	0.94	1.40	0.63	0.000	100.0	N		0.014	N(a)
Other												
Nitrate/Nitrite	mg/kg		22	36.36	150.00	1.08	0.000	45.5	N		440,000	

ENDNOTES:

The calculation of the sample mean quantifies each non-detect as a value equal to half the detection limit. *For samples with the max value less than the detection level, the value of the mean may exceed the value of the max.*

NA = Not Applicable

ARAR = Applicable or Relevant and Appropriate Requirement

PRG = Preliminary Remediation Goals

(a) Natural uranium source; not contamination from RFP see section 4.2.2.5

1) Number of decimal places do not present scientifically valid significant figures
2) p-Value is a statisically derived value for comparison of a sample to background:
   p-Value ≤ 0.05 - Sample is statisically significantly higher than background
   p-Value > 0.05 - Sample is not statistically different from background
3) See text for development of ARARs and PRGs

APPENDIX D
PRG DETERMINATION METHOD

PRELIMINARY REMEDIATION GOALS

By definition, chemical-specific PRGs are concentration goals for individual chemicals for specific medium and land use combinations at CERCLA sites. PRGs are intended to provide remedial design staff with long-term cleanup targets to use during analysis and selection of remedial alternatives (EPA 1991). EPA (1991) describes two general sources for chemical-specific PRGs: (1) concentrations based on ARARs, and (2) concentrations based on risk assessment.

The PRGs presented in this section are risk-based and were developed using federal EPA guidance (EPA 1991). The PRGs were based on readily available, existing information using EPA toxicity criteria and standard default exposure assumptions.

RISK-BASED PRELIMINARY REMEDIATION GOALS

In developing risk-based PRGs, the potential media and chemicals of concern at OU 11 were evaluated, and the site's land-use conditions were considered. Based on this review, PRGs for the protection of human health were developed for chemicals in groundwater and soils. All chemicals detected in these media were conservatively included when calculating PRGs. Furthermore, risk-based PRGs were calculated assuming residential scenarios, and incorporated conservative EPA default exposure parameters. It should be noted that all potential human exposure pathways were not considered in the development of PRGs (e.g., dermal exposures) and that exposure parameters based on site-specific information may be different from EPA default exposure. However, for this screening level analysis, EPA default parameters have been used except where expressly noted.

The calculation of risk-based PRGs relies on chemical-specific toxicity criteria, specifically EPA-derived cancer slope factors and reference doses. The non-radionuclide criteria were taken from EPA (1993a,b) and the radionuclide criteria were taken from EPA (1993b). The toxicity values for the chemicals detected at OU 11 are presented on each PRG table. It should be noted that if both a carcinogenic and noncarcinogenic risk-based PRG are calculated for a particular chemical, then the lower of the two values is considered the appropriate risk-based PRG for use during subsequent analysis and comparison (EPA 1991). When both can be developed, those based on carcinogenic effects are consistently lower than those based on noncarcinogenic effects.

The next sections present the equations that were used to calculate risk-based PRGs for groundwater and soil exposures. Equations for calculating risk-based PRGs are presented separately for chemicals exhibiting carcinogenic and noncarcinogenic effects.

Groundwater PRG Equations

PRGs for groundwater were calculated assuming residential exposures via ingestion. The equations and parameters used for groundwater PRGs were based on EPA (1991) guidance.

The equation used to calculate PRGs for chemicals exhibiting carcinogenic effects is as follows:

$$C_{gw} = \frac{TR * BW * AT_c * 365\ days/year}{SF_o * 10^{-3}\ mg/\mu g * EF * ED * IR_{water}}$$

The equation used to calculated PRGs for radionuclides exhibiting carcinogenic effects is as follows:

$$C_{gw} = \frac{TR}{EF * ED * SF_o * IR_{water}}$$

where:

C_{gw}	=	chemical concentration in water (µg/L for non-radionuclies or pCi/L for radionuclides),
TR	=	target excess individual lifetime cancer risk (10^{-6}),
BW	=	body weight (70 kg),
AT_c	=	averaging time for carcinogenic effects (70 years),
EF	=	exposure frequency (350 days/year),
ED	=	exposure duration (30 years),
SF_o	=	oral cancer slope factor [$(mg/kg\text{-}day)^{-1}$ for non-radionuclides or $(pCi)^{-1}$ for radionuclides], and
IR_{water}	=	daily water ingestion rate (2 L/day).

The equation used to calculate PRGs for chemicals exhibiting noncarcinogenic effects is:

$$C_{gw} = \frac{THI * BW * AT_{nc} * 365\ days/year}{1/RfD_o * 10^{-3}\ mg/\mu g * EF * ED * IR_{water}}$$

where:

C_{gw}	=	chemical concentration in water (µg/L),
THI	=	target hazard index (1),
BW	=	body weight (70 kg),
AT_{nc}	=	averaging time for noncarcinogenic effects (30 years),
EF	=	exposure frequency (350 days/year),
ED	=	exposure duration (30 years),
RfD_o	=	oral chronic reference dose (mg/kg-day), and
IR_{water}	=	daily water ingestion rate (2 L/day).

Soil PRG Equations

PRGs for chemicals in soil were calculated assuming a residential scenario. PRGs were derived considering inhalation of particulates and ingestion routes combined.

The equation used to develop residential scenario PRGs for chemicals exhibiting carcinogenic effects is as follows:

$$Cs = \left[\frac{TR * AT_c * 365\ days/year}{EF}\right] * \left[\frac{1}{SF_o * 10^{-6}\ kg/mg * IR_{soil\,adj}} + \frac{BW}{SF_I * ED * IR_{air} * (1/PEF)}\right]$$

The equation used to develop residential scenario PRGs for radionuclides exhibiting carcinogenic effects is as follows:

$$Cs = \frac{TR}{[(SF_o * 10^{-6}\ g/mg * EF * IR_{soil\,adj}) + (SF_i * 10^{3}\ g/kg * ED * EF * IR_{air} * (1/PEF)) + (SF_e * 10^{3}\ g/kg * ED * D * SD * (1-S_e) * T_e)]}$$

where:

C_s	=	chemical concentration in soil (mg/kg for non-radionuclides or pCi/g for radionuclides),
TR	=	target excess individual lifetime cancer risk (10^{-6}),
BW	=	body weight (70 kg),
AT_c	=	averaging time for carcinogenic effects (70 years),
EF	=	exposure frequency (350 days/year),
ED	=	exposure duration (30 years),
SF_o	=	oral cancer slope factor [$(mg/kg\text{-}day)^{-1}$ for non-radionuclides or $(pCi)^{-1}$ for radionuclides],
$IR_{soil/adj}$	=	soil ingestion rate (114 mg-yr/kg-day for non-radionuclides or 3,600 mg-yr/day for radionuclides),
SF_i	=	inhalation cancer slope factor [$(mg/kg\text{-}day)^{-1}$ for non-radionuclides or $(pCi)^{-1}$ for radionuclides],
IR_{air}	=	inhalation rate (20 m^3/day),
PEF	=	particulate emission factor (2.50×10^7 m^3/kg),

and for radionuclides (external exposure radiation):

SF_e	=	external exposure slope factor (risk/yr per pCi/m^2),
D	=	depth of radionuclides in soil (0.1 m),
SD	=	soil density (1.43×10^3 kg/m^3),
S_e	=	gamma shielding factor (0.2 unitless), and
T_e	=	gamma exposure factor (1 unitless).

The PEF is site-specific and is derived from data on total suspended particulate levels reported in the 1991 RFP Site Environmental Report.

The equation used to calculate PRGs for chemicals exhibiting noncarcinogenic effects is:

$$C_s = [\frac{THI * AT_{nc} * 365\ days/year}{EF}] * [\frac{1}{(1/RfD_o) * 10^{-6}\ kg/mg * IR_{soil\,adj}} + \frac{BW}{(1/RfD_i) * ED * IR_{air} * (1/PEF)}]$$

where:

C_s	=	chemical concentration in soil (mg/kg),
THI	=	target hazard index (1),
BW	=	adult body weight (70 kg),
AT_{nc}	=	averaging time for noncarcinogenic effects (30 years),
ED	=	exposure duration (30 years),
EF	=	exposure frequency (350 days/year),
RfD_o	=	oral chronic reference dose (mg/kg-day),
IR_{soil}	=	soil ingestion rate (114 mg-yr/kg-day),
RfD_i	=	inhalation chronic reference dose (mg/kg-day),
IR_{air}	=	inhalation rate (20 m^3/day),
PEF	=	particulate emission factor (2.50×10^7 m^3/kg).

The equations and parameters shown above are based on EPA (1991) guidance. The age-adjusted ingestion factor for non-radionuclides (114 mg-yr/kg-day) was developed by EPA (1991) assuming six years of exposure as a 15-kg child ingesting 200 mg soil/day, plus 24 years of exposure as a 70-kg adult ingesting 100 mg soil/day. The age-adjusted soil ingestion factor for radionuclides (3,600 mg-yr/day) was also developed by EPA (1991) based on six years of exposure of a child ingesting 200 mg soil/day, plus 24 years of exposure as an adult ingesting 100 mg soil/day.

REFERENCES

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1993a. Integrated Risk Information System (IRIS). Environmental Criteria and Assessment Office, Cincinnati, Ohio.

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1993b. Health Effects Assessment Summary Table (HEAST). Prepared by Office of Health and Environmental Assessment. Environmental Criteria and Assessment Office, Cincinnati, Ohio for the Office of Solid Waste and Emergency Response, Office of Emergency and Remedial Response, Washington, DC. FY-1993.

ENVIRONMENTAL PROTECTION AGENCY (EPA). 1991. Risk Assessment Guidance for Superfund: Volume 1 - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals). Interim. Office of Emergency and Remedial Response. December.

OU 11

RISK-BASED PRELIMINARY REMEDIATION GOALS (PRGs)
FOR CHEMICALS DETECTED IN SOIL
[Residential Scenario with particulate inhalation]

Chemicals Exhibiting Carcinogenic Effects	External Exposure Slope Factor (risk/yr/pCi/m2)	Oral Slope Factor [(mg/kg-day)-1 or (pCi)-1]	Inhalation Slope Factor [(mg/kg-day)-1 or (pCi)-1]	Risk-Based PRG Based on Target Risk of 1x10-6 (mg/kg or pCi/g)
Radionuclides:				
Pu-239+240	2.7E-11	2.3E-10	3.8E-08	1.1E-02
Am-241	4.9E-09	2.4E-10	3.2E-08	5.9E-05
U-233+234	4.2E-11	1.6E-11	2.7E-08	6.9E-03
U-235	2.4E-07	1.6E-11	2.5E-08	1.2E-06
U-238	2.1E-11	1.6E-11	2.4E-08	1.4E-02
H-3	---	5.4E-14	7.8E-14	1.5E+04
Metals:				
Arsenic		1.8E+00	5.0E+01	4.6E+00
Beryllium		4.3E+00	8.4E+00	2.5E+01
Cadmium		---	6.1E+00	3.5E+01
Chromium VI		---	4.1E+01	5.2E+00
Nickel		---	1.7E+00	1.3E+02

Chemicals Exhibiting Noncarcinogenic Effects	Oral Reference Dose (mg/kg-day)	Inhalation Reference Dose (mg/kg-day)	Risk-Based PRG Based on a Target Hazard Quotient of 1 (mg/kg)
Metals:			
Aluminum	---	---	---
Antimony	4E-04	---	1.1E+02
Arsenic	3E-04	---	8.2E+01
Barium	7E-02	1.0E-04	2.8E+04
Beryllium	5E-03	---	1.4E+03
Cadmium	1E-03 (a)	---	2.7E+02
Calcium	---	---	---
Cesium	---	---	---
Chromium III	1E+00	---	2.7E+05
Chromium VI	5E-03	5.0E-07	1.4E+03
Cobalt	---	---	---
Copper	3.7E-02 (b)	---	1.0E+04
Cyanide	2.2E-02	---	6.0E+03
Iron	---	---	---
Lead	---	---	---
Lithium	---	---	---
Magnesium	---	---	---
Manganese	1.4E-01 (a)	1.0E-04	4.8E+04
Mercury	3E-04	9.0E-05	8.3E+03
Molybdenum	5E-03	---	1.4E+03
Nickel	2E-02	---	5.5E+03
Nitrate	1.6E+00	---	4.4E+05
Potassium	---	---	---
Selenium	5E-03	---	1.4E+03
Silver	5E-03	---	1.4E+03
Sodium	---	---	---
Strontium	6E-01	---	1.6E+05
Thallium	8E-05 (c)	---	2.2E+01
Tin	6E-01	---	1.6E+05
Vanadium	7E-03	---	1.9E+03
Zinc	3E-01	---	8.2E+04

--- = Toxicity criteria not available.

(a) Based on and is used to assess non-aqueous exposures.
(b) EPA has reported a drinking water standard for copper of 1.3 mg/L. This value was converted to a dose assuming a 70-kg individual ingests 2 L/day of water.
(c) The thallium sulfate RfD was conservatively used to calculate the PRG for thallium.

Parameters:	Range Name:	Value:	Source:	
Target Risks:				
Target Risk, 10-6	TR6	1E-06	---	
Target Hazard Quotient:				
1 is the Target	THQ	1	---	
Exposure Parameters:				
Averaging Time (years)				
Carcinogens	LIFE	70	Standard Default	
Noncarcinogens	Same as ED	30	Standard Default	
Exposure Frequency (days/year)	EF	350	Standard Default	
Exposure Duration (years)	ED	30	Standard Default	
Conversion Factor (days/year)	Days	365	Standard Default	
Adult body weight (kg)	BW	70	Standard Default	
Soil Ingestion Rate (mg-yr/kg-day)	IRSoil	114	Standard Default	(non-radionuclides)
Soil Ingestion Rate (mg-yr/day)	IRSoil	3600	Standard Default	(radionuclides)
Inhalation Rate (m3/day)	IRair	20	Standard Default	
Particulate Emission Factor (PEF)	PEF	2.50E+07	meters3/kg	
Parameters for radionuclides:				
Depth of radionuclides in soil	D	0.1	meters	
Soil Density	SD	1.43E+03	kg/m3	
Gamma Shielding Factor	SE	0.2	unitless	
Gamma Exposure Factor	TE	1	unitless	

OU 11

RISK-BASED PRELIMINARY REMEDIATION GOALS (PRGs) FOR CHEMICALS DETECTED IN GROUNDWATER

Chemicals Exhibiting Carcinogenic Effects	Oral Slope Factor [(mg/kg-day)-1 or (pCi)-1]	Inhalation Slope Factor [(mg/kg-day)-1 or (pCi)-1]	Risk-Based PRG Based on Target Risk of 1x10-6 (ug/L or pCi/L)
Radionuclides:			
Pu-239+240	2.3E-10	NA	2.1E-01
Am-241	2.4E-10	NA	2.0E-01
U-233+234	1.6E-11	NA	3.0E+00
U-235	1.6E-11	NA	3.0E+00
U-238	1.6E-11	NA	3.0E+00
H-3	5.4E-14	NA	8.8E+02
Metals:			
Arsenic	1.75E+00	NA	4.9E-02
Beryllium	4.3E+00	NA	2.0E-02

Chemicals Exhibiting Noncarcinogenic Effects	Oral Reference Dose (mg/kg-day)	Inhalation Reference Dose (mg/kg-day)	Risk-Based PRG Based on a Target Hazard Quotient of 1 (ug/L)
Metals:			
Aluminum	---	NA	---
Antimony	4E-04	NA	1.5E+01
Arsenic	3E-04	NA	1.1E+01
Barium	7E-02	NA	2.6E+03
Beryllium	5E-03	NA	1.8E+02
Cadmium	5E-04 (a)	NA	1.8E+01
Calcium	---	NA	---
Cesium	---	NA	---
Chromium III	1E+00	NA	3.7E+04
Chromium IV	5E-03	NA	1.8E+02
Cobalt	---	NA	---
Copper	3.7E-02 (b)	NA	1.4E+03
Cyanide	2.2E-02	NA	8.0E+02
Iron	---	NA	---
Lead	---	NA	---
Lithium	---	NA	---
Magnesium	---	NA	---
Manganese	5E-03 (a)	NA	1.8E+02
Mercury	3E-04	NA	1.1E+01
Molybdenum	5E-03	NA	1.8E+02
Nickel	2E-02	NA	7.3E+02
Nitrate	1.6E+00	NA	5.8E+04
Potassium	---	NA	---
Selenium	5E-03	NA	1.8E+02
Silver	5E-03	NA	1.8E+02
Sodium	---	NA	---
Strontium	6E-01	NA	2.2E+04
Thallium	8E-05 (c)	NA	2.9E+00
Tin	6E-01	NA	2.2E+04
Vanadium	7E-03	NA	2.6E+02
Zinc	3E-01	NA	1.1E+04

NA = Inhalation toxicity criteria are not applicable. Inhalation of metals will not occur as these chemicals are not volatile.
--- = Toxicity criteria not available.

(a) Based on and is used to assess aqueous exposures.
(b) EPA has reported a drinking water standard for copper of 1.3 mg/L. This value was converted to a dose assuming a 70-kg individual ingests 2 L/day of water.
(c) The thallium sulfate RfD was conservatively used to calculate the PRG for thallium.

Parameters:	Range Name:	Value:	Source:
Target Risks:			
Target Risk, 10-6	TR6	1E-06	---
Target Hazard Quotient:			
1 is the Target	THQ	1	---
Exposure Parameters:			
Body Weight (kg)	BW	70	Standard Default
Averaging Time (years)			
Carcinogens	LIFE	70	Standard Default
Noncarcinogens	Same as ED	30	Standard Default
Exposure Frequency (days/year)	EF	350	Standard Default
Exposure Duration (years)	ED	30	Standard Default
Daily Ingestion Rate (L/day)	IRW	2	Standard Default
Conversion Factor (days/year)	Days	365	

APPENDIX E

ECOLOGICAL SAMPLNG TABLES

Table E-1 Sampling Matrix

TAXON/TASKS (ENDPOINTS)	COLLOCATION	RECOMMENDED FIELD SAMPLING METHODS	FIELD HOURS
TERRESTRIAL			
VEGETATION	ALL		
ECOLOGICAL			
Total Plant Cover		60, 50-m line-intercept transects	60
Cover By Plant Community Type		60, 50-m line-intercept transects	
Cover By Individual Species		60, 50-m line-intercept transects	
Species Richness		60, 50-m belt transects	60
Density (woody plants and cacti)		60, 50-m belt transects	
Herbaceous Production		60, 0.25 sq. meter quadrants/type	60
Height (cm)		60, 0.25 sq. meter quadrants/type	
Species Presence/Absence			
TISSUE			12
ARTHROPODS	ALL		
ECOLOGICAL		3 replicates/12 grids; sweep netting	
Taxon Richness			36
Biomass			
Taxon Presence/Absence			
Taxon Relative Abundance			
TISSUE (Grasshoppers)		12 samples, 25-g samples/grid; sweep netting	12
BIRDS			
ECOLOGICAL		5, 2 ha plots; 100-m x 200-m plots; 6 replicates	
Species Relative Abundance			6
Species Richness			
Species Density Per Hectare			
Species Presence/Absence			

Table E-1 Sampling Matrix

Matrix con't			
SMALL MAMMALS	ALL		
ECOLOGICAL		Live trap grid/lines at 5-m intervals (25 traps); 3 trap nights	
Species Richness			36
Weight to Length Ratio			
Sex			
Reproductive Status & Age			
Species Presence/Absence			
Species Abundance (spss.#/night)			
TISSUE		25-g samples	12
LARGE MAMMALS			
ECOLOGICAL		Count in 5 vegetation-belt transects	
Species Relative Abundance			20
Species Presence/Absence			2
Pellet Counts Per Hectare		Count pellets within 12 grids	
AQUATIC			
BIOTA			
ECOLOGICAL		1 surface water site; hand pick	
Species Richness (qualitative)			10
Species Presence/Absence			
TISSUE		3 species per endpoint; 25-g sample	10
REPTILES AND AMPHIBIANS			
TISSUE		3, 25-g samples/species	
Anurans		Minnow traps, hands	10
Uropods		Minnow traps, hands	
FISH (Not Expected)			
ECOLOGICAL		Minnow traps	
Species Richness			8
Species Presence/Absence			16
TISSUE		3, 25-g sample; minnow traps	16

Table E-1 Sampling Matrix

Matrix con't			
CRUSTACEANS			
Species Richness		Hand pick, minnow traps	
Species Presence/Absence			
TISSUE		5, 25-g sample; hand pick, minnow traps	

Table E-1 Sampling Matrix

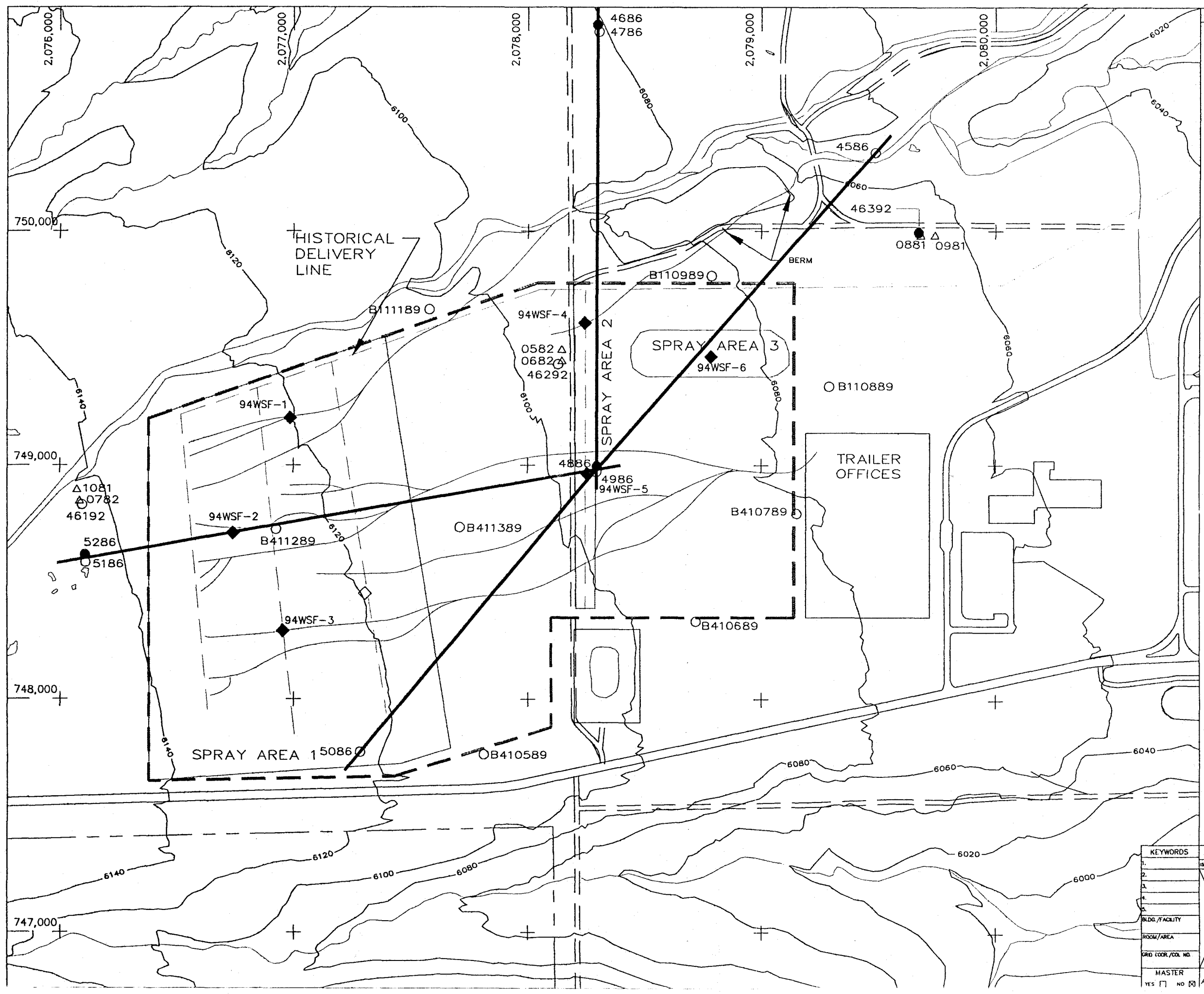
HOURS BREAKDOWN			
TOTAL FIELD HOURS			386
TOTAL DATA ANALYSIS HOURS			
STAKING OF SITES		12 grids	24
VEGETATION MAPPING			8
EE REPORT			
AGENCY PRESENTATIONS (3 EPA meetings)			24
DRAFT EE REPORT WRITING			
REVISIONS			50
FINAL REPORT			40

Table E-2 Sampling Design

TAXON	SPRAYED AREAS #1	#2	#3	NON-SPRAYED AREAS	REFERENCE AREAS	TOTAL SAMPLES
GRIDS NEEDED (5x5)	2	1	1	4	4	12
TERRESTRIAL						
Vegetative Covers (5/grid)	10	5	5	20	20	60
Vegetation Belts (5/grid)	10	5	5	20	20	60
Vegetation Quadrants (5/grid)	10	5	5	20	20	60
Arthropods (1/grid)	2	1	1	4	4	12
Birds (5, 2-ha plots x 6 replicates, 500-m transect)	30 for entire area				60 for area	90
Small Mammals (#of grids x 25 traps x 3 trap nights)	150	75	75	300	300	900
Large Mammals:						
Pellet Counts	2	1	1	4	4	12
Relative Abundance Transects	1 (pooled data)			1	1	3
TISSUE						
Terrestrial Vegetation (# of grids x 3 replicates; 25-g sample)	6	3	3	12	12	36
Small Mammals (1/species/grid)	2	1	1	4	4	12
Arthropods (1, 25-g/site)	1 (pooled data)			1	1	12
AQUATIC	**Surface Water Pond #128**				**Lindsay Pond**	
BIOTA						
5 replicates per species						
Zoobenthos	5				5	10
Periphyton	5				5	10
Phytoplankton	5				5	10
Zooplankton	5				5	10

Table E-2 Sampling Design

TISSUE				
3 replicates, 25-g sample/taxon from #128 pond (if possible)				
Periphyton	3 (pooled data)		2	5
Macrophyte	3		2	5
Zoobenthos (not expected)	3 (pooled data)		2	5
Benthos (3 replicates x 3 species)	9		9	18
REPTILES & AMPHIBIANS				
TISSUE				
5 replicates, 25-g samples (either one of the following)				
Anurans	3		3	6
Uropods	3		3	6
CRUSTACEANS				
TISSUE	3		3	6



PART	QUAN.	DESCRIPTION	MATERIAL

94WSF-1 ◆ PROPOSED GROUNDWATER MONITORING WELL LOCATIONS

B110989 ○ ALLUVIAL MONITORING WELL

4686 ● BEDROCK MONITORING WELL

0582 △ PRE-1986 MONITORING WELL

RCRA WASTE MANAGEMENT AREA

SPRAY AREAS

DRAINAGE FLOW LINE

6040 GROUND CONTOUR

PIPING (HISTORICAL)

SECTION CUT

N

SCALE 1" = 400'

400 200 0 800

300 100 400

CONTOUR INTERVAL = 20'

KEYWORDS	ISSUE	DESCRIPTION	DATE	DOE	CLASS	JOB NO
	A	ORIGINAL ISSUE	10/05/93 MWB KAS MFK			
1.			RFP			
2.						
3.						
4.						
5.						
BLDG./FACILITY						
ROOM/AREA						
GRID COOR./COL NO.						

DESIGNED BELL
DRAWN SCHACKLIN
CHECKED KRAESKI
APPROVED

MASTER YES ☐ NO ☒

SCALE: AS NOTED

SUBMITTED
APPROVED RFP
APPROVED

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS AREA OFFICE GOLDEN, COLORADO

Rocky Flats Plant
GOLDEN, COLORADO 80401

OPERABLE UNIT 11 - WEST SPRAY FIELD

Locations of Proposed Monitoring Wells

SIZE	DRAWING NUMBER	ISSUE	SHEET
B	FIGURE 4-2	A	OF

PART	QUAN.	DESCRIPTION	MATERIAL

RCRA WASTE MANAGEMENT AREA

SPRAY AREAS

DRAINAGE FLOW LINE

6040 GROUND CONTOUR

PIPING (HISTORICAL)

2,076,000 2,077,000 2,078,000 2,079,000 2,080,000

750,000 749,000 748,000 747,000

HISTORICAL DELIVERY LINE

BERM

SPRAY AREA 2

SPRAY AREA 3

SPRAY AREA 1

HISTORICAL IRRIGATION LINES

TRAILER OFFICES

6020 6040 6060 6080 6100 6120 6140

N

SCALE 1" = 400'

400 200 0 800

300 100 400

CONTOUR INTERVAL = 20'

KEYWORDS	A	ORIGINAL ISSUE	12/18/91	MWB	KAS	MPK				
1.	ISSUE	DESCRIPTION	DATE	RFP		DOE	CLASS	JOB NO		
2.										
3.										
4.										
5.										
BLDG./FACILITY										
ROOM/AREA										
GRID COOR./COL NO.										
MASTER YES ☐ NO ☒										

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS AREA OFFICE GOLDEN, COLORADO

DESIGNED	BELL
DRAWN	SCHACKLIN
CHECKED	KRAESKI
APPROVED	

Rocky Flats Plant

GOLDEN, COLORADO 80401

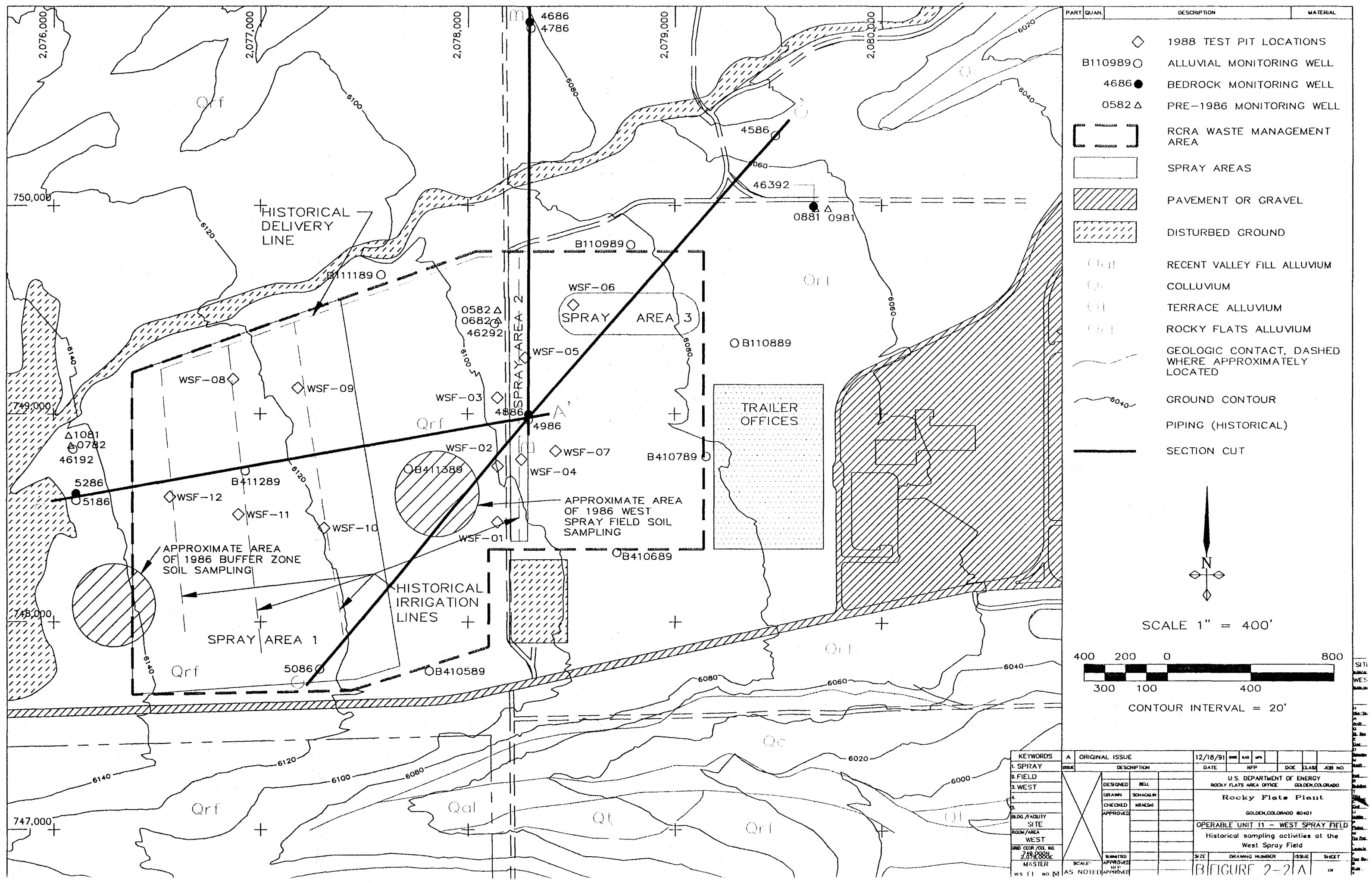
OPERABLE UNIT 11 – WEST SPRAY FIELD

AREAS OF SPRAY APPLICATION

SCALE: AS NOTED

SUBMITTED APPROVED RFP APPROVED

SIZE	DRAWING NUMBER	ISSUE	SHEET
B	FIGURE 1-1	A	OF



PART | QUAN. | DESCRIPTION | MATERIAL
1988 TEST PIT LOCATIONS
B110989 ALLUVIAL MONITORING WELL
4686 BEDROCK MONITORING WELL
0582 PRE-1986 MONITORING WELL
RCRA WASTE MANAGEMENT AREA
SPRAY AREAS
PAVEMENT OR GRAVEL
DISTURBED GROUND
RECENT VALLEY FILL ALLUVIUM
COLLUVIUM
TERRACE ALLUVIUM
ROCKY FLATS ALLUVIUM
GEOLOGIC CONTACT, DASHED WHERE APPROXIMATELY LOCATED
GROUND CONTOUR
PIPING (HISTORICAL)
SECTION CUT
N
SCALE 1" = 400'
400 200 0 800
300 100 400
CONTOUR INTERVAL = 20'
HISTORICAL DELIVERY LINE
SPRAY AREA 1
SPRAY AREA 2
SPRAY AREA 3
TRAILER OFFICES
APPROXIMATE AREA OF 1986 WEST SPRAY FIELD SOIL SAMPLING
APPROXIMATE AREA OF 1986 BUFFER ZONE SOIL SAMPLING
HISTORICAL IRRIGATION LINES
WSF-01
WSF-02
WSF-03
WSF-04
WSF-05
WSF-06
WSF-07
WSF-08
WSF-09
WSF-10
WSF-11
WSF-12
B110989
B111189
B110889
B411389
B411289
B410789
B410689
B410589
4686
4786
4586
46392
0881
0981
0582
0682
46292
4886
4986
1081
0782
46192
5286
5186
5086
2,076,000
2,077,000
2,078,000
2,079,000
2,080,000
750,000
749,000
748,000
747,000
Qrf
Qal
Qt
Qc
KEYWORDS
1. SPRAY
2. FIELD
3. WEST
BLDG./FACILITY SITE
ROOM/AREA WEST
MASTER
A ORIGINAL ISSUE
12/18/91
ISSUE DESCRIPTION DATE RFP DOE CLASS JOB NO
DESIGNED BELL
DRAWN SCHACKLIN
CHECKED KRAESKI
APPROVED
SUBMITTED
APPROVED
SCALE AS NOTED
U.S. DEPARTMENT OF ENERGY
ROCKY FLATS AREA OFFICE GOLDEN, COLORADO
Rocky Flats Plant
GOLDEN, COLORADO 80401
OPERABLE UNIT 11 - WEST SPRAY FIELD
Historical sampling activities at the West Spray Field
SIZE DRAWING NUMBER ISSUE SHEET
B FIGURE 2-2 A

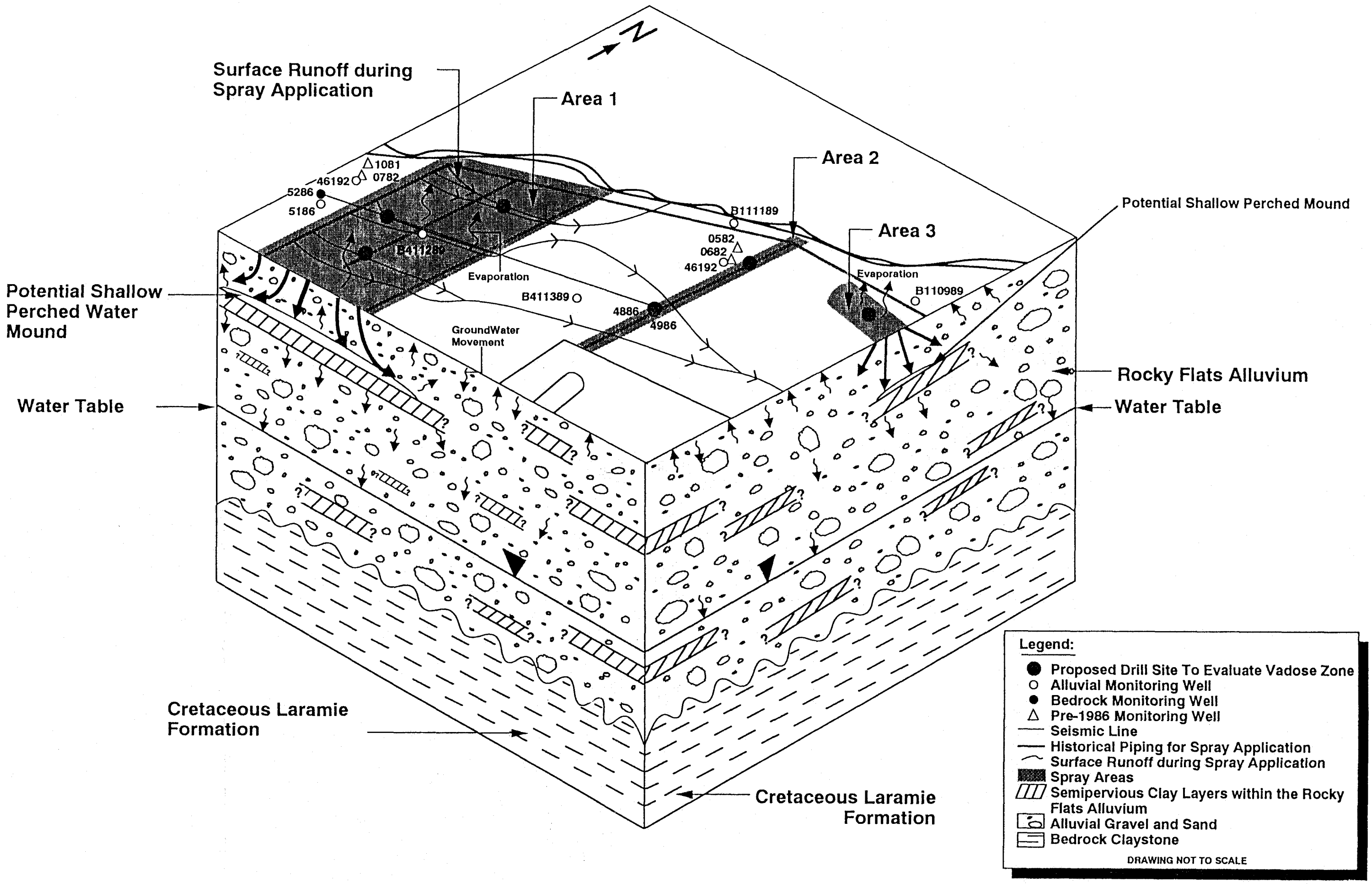



Figure 3-1 Schematic Diagram of Conceptual Model – West Spray Field